

**Essays on International Capital Flows and
Productivity Growth**

by

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Abstract

Contrary to traditional neoclassical growth models, recent decades have seen a number of developing economies running sizable current account surpluses. In response to “new mercantilist” explanations of this phenomenon that relate holdings of foreign assets to higher levels of economic growth, this paper presents a theoretical model of a small open developing economy that permits a welfare analysis of mercantilist policies and importantly answers the question of whether mercantilist motives alone can explain the recent high levels of observed foreign asset holdings. Using a calibration to match the characteristics of China, the model shows that while such policies may lead to significant welfare gains, consumers’ desires to smooth consumption generally preclude a positive current account balance under most parameterizations. Deliberate foreign asset accumulation may therefore be welfare reducing, or mercantilist motives may provide only one component of a fuller explanation of current account surpluses.

The theoretical framework can be extended to consider the welfare effects of international capital controls and real exchange rate changes in a multi-country setting.

I present a dynamic open-economy macro model with an endogenously determined rate of interest on internationally-mobile assets. All countries produce tradable and nontradable goods using technology that converges over time to a global frontier. The model quantifies the welfare effects of the unilateral implementation of capital controls that depreciate the real exchange rate on economies both already at and converging to the technological frontier. In certain contexts, I demonstrate that such government interventions may constitute “beggar-thy-neighbor” policies, such that developing economies that do not implement similar policies may experience a welfare loss relative to a global laissez-faire setting.

Next, I present empirical evidence on the relationship between exposure to international markets and productivity gains in a novel way. Total factor productivity (TFP) is estimated for an international panel of individual firms, while controlling for input selection endogeneity and market exit bias. These estimates are then used to construct country-level estimates of aggregate productivity, which are disaggregated between tradable and nontradable sectors using an objective criterion based on each country’s actual industry-level export intensity. Using this unique data set, I test the common theoretical assumption that production activity in the tradable-sector is an impetus for faster productivity growth in the economy using a structural panel VAR analysis, finding positive effects of industrial labor shares on TFP growth. The data also provides further evidence of the expected relationship between sectoral growth differentials and exchange rates predicted by the Harrod-Balassa-Samuelson effect.

Furthermore, the data provides evidence of cross-country convergence in tradable-sector productivity over time. Finally, consideration is given as to whether these relationships differ significantly between developed and developing economies, as might be induced by the existence of a global technology frontier.

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Dedication

To Catherine Morris, Carmen Rabe, and Alan Rabe

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Introduction

In a famous essay, Lucas (1990) posed the question, “Why doesn’t capital flow from rich to poor countries?” According to standard neoclassical economic models, relatively capital-starved developing countries ought to exhibit relatively higher marginal productivities of capital and therefore attract more investment funds from around the world. However, capital flows from developed economies to developing economies have not only been somewhat modest, but starting in the 2000s the global economy began to display substantial “uphill” capital flows moving in the opposite direction: from poor to rich. Even more curiously, these capital outflows were found to be positively associated with higher economic growth by Prasad, et al (2007) and faster productivity growth by Gourinchas and Jeanne (2011).

In discussions of the rationale behind the recent phenomena of some emerging economies exporting substantial sums of capital by running persistent current account surpluses, particularly China (See Figure 1.1), and accumulating unprecedented stockpiles of foreign reserves, particularly in developing Asia (see Figure 1.2), a commonly floated explanation is that of “new mercantilism,” i.e. the theory that asset

accumulation in emerging markets is a by-product of the promotion of exports to developed nations in order to facilitate the creation of jobs in industry and accelerate domestic economic growth. However, many of these explanations have been limited to stylized narratives (Dooley, et al 2003) and/or suggestive empirics (Rodrik 2008).

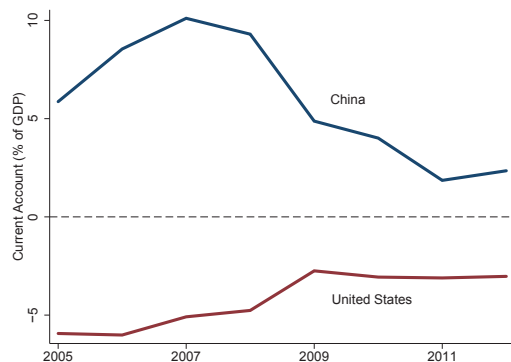


Figure I.1: China and U.S. current accounts as a percentage of GDP. (Source: World Bank - World Development Indicators)

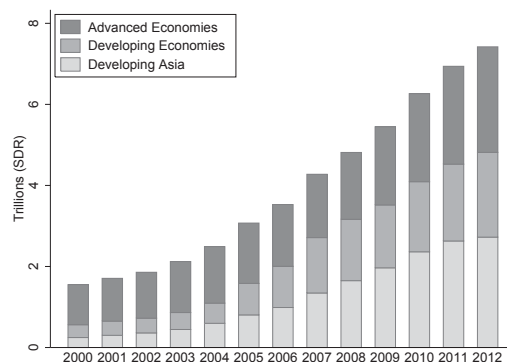


Figure I.2: Global total reserves excluding gold in trillions of Special Drawing Rights (Source: IMF - International Financial Statistics)

In recent years, the idea of “new mercantilism”¹ has experienced growing popularity in some areas of academia and is often invoked implicitly in popular media. Dooley, Folkerts-Landau, and Garber (2004) offered perhaps the most concise definition when stating, “Exports mean growth.” Alternatively, Dani Rodrik (2013) offers a fuller description:

“It is more accurate to think of mercantilism as a different way to organize the relationship between the state and the economy...in pursuit of common objectives, such as domestic economic growth. Mercantilists view trade as a means of supporting domestic production and employment, and prefer to spur exports rather than imports.”

¹The breadth of meaning implied by the label of “new mercantilism” has often varied by author. This chapter follows Aizenman and Lee (2010) in conceptualizing a “mercantilist” accumulation of assets as having the goal of export competitiveness and/or real economic growth, as opposed to pure insurance purposes.

Thus, at the heart of mercantilism lies the belief that the exportation of goods and services is intrinsically desirable and should be actively encouraged. In other words, the accumulation of gold that was the principal objective of the “mercantilism” of the 19th century has been supplanted by the accumulation of foreign assets in its modern incarnation, though the means of financing both has remained the same: current account surpluses. However, just as Adam Smith famously argued in “The Wealth of Nations” that ownership of bullion is not fundamentally equivalent to prosperity, the sense in endlessly accumulating foreign assets is not immediately self-evident. After all, how does one gain by continually working day-after-day in return for I.O.U.s ad infinitum? Therefore, any satisfying explanation of the virtues of “new mercantilism” must answer the following two important questions: 1) How can policy induce exports? and 2) How do exports drive economic growth?

The key motivation at the core of this dissertation that offers an answer to these questions is that having more of an economy’s labor force engaged in the tradable-goods sector allows for faster imitation and adoption of the cutting-edge technologies and best practices employed by relatively advanced economies competing in the international market, thus leading to higher aggregate domestic productivity. If individual domestic firms in the tradable-goods sector do not internalize the impact of their hiring decisions on productivity growth as it affects the economy as a whole, then the government has an opportunity to introduce welfare-increasing policies that lead to a higher allocation of labor to the production of tradable goods and therefore a faster

rate of technological and economic growth. While a government may in theory have a broad portfolio of policies to choose from in order to address this externality, I argue that in reality many governments' feasible sets of policy options are restricted to the use of capital controls as a second-best alternative. Therefore, I focus on the implementation of restrictions on domestic consumers' ability to access international borrowing and lending markets as a means of achieving the government's objective of faster growth and higher lifetime welfare.

The dissertation proceeds as follows: The first chapter considers the impacts of capital controls on economic growth and welfare in the context of a small open economy (SOE) and assesses the applicability of "new mercantilism" to explaining the recent experience of China using a calibrated theoretical model. The following chapter extends the analysis to a multi-country framework and discusses the implications of a developing economy's unilateral use of capital controls on its developed and fellow developing trading partners. The final chapter outlines the use of firm-level data to construct novel aggregate estimates of productivity and uses these estimates in a robust empirical estimation of the assumption underlying the previous theoretical models that tradable-sector activity facilitates faster productivity growth.

Chapter 1

A Welfare Analysis of “New Mercantilist” Foreign Asset Accumulation

This chapter builds on the narrative of Dooley, et al (2003) and the empirical evidence of Rodrik (2008) that motivate the basic mercantilist story of growth via export-promotion by making an explicit assumption about the nature of the relationship between the tradable-goods sector and economic growth. By taking the mercantilist hypothesis as a starting point, this chapter then provides a positive assessment of the capability of mercantilism to explain the recent lending behavior of China, the so-called “leading bearer of the mercantilist torch” (Rodrik (2013)).

This chapter fills a gap in the existing literature by presenting a dynamic model

of a developing small open economy that allows for a full welfare analysis of “new mercantilist” policy, calibrated to match the growth of China, the largest global holder of foreign reserves. The main insight provided by the model is that – despite significant potential welfare gains – the proposition of mercantilist hoarding of foreign assets by way of capital controls can not explain current account surpluses under realistic calibrations. Overall, mercantilism may provide a component of the rationale behind foreign asset accumulation, but additional motivation is needed to fully justify the levels currently observed in some emerging economies, especially China.

The key assumption driving growth in the model presented in this chapter is related to the allocation of resources to the production of tradable goods. Most popular mercantilist stories explain the promotion of exports by exchange rate depreciation. However, in the absence of persistent price-stickiness, such an approach is problematic in that it may only have short-term effects and/or lead to unwanted inflation. Furthermore, as shown in Jeanne (2012), a policy of maintaining an undervalued exchange rate in a growing economy may incur significant welfare losses. Moreover, exchange rate manipulation alone doesn’t provide an answer to the important question of how the act of exporting enables greater economic growth. Therefore, since exchange rate dynamics are not essential to a mercantilist story,¹ I focus instead on presenting a real model that is consistent with the concept of “new mercantilism”

¹In other words, a depreciated exchange rate is not a necessary condition for demonstrating welfare-increasing mercantilist policy. In the interest of simplicity, additional economic frictions that could otherwise be used to introduce exchange rate undervaluation are omitted from the model presented.

by way of the following two important assumptions: 1) the government uses strict capital flow controls to direct resources into the tradable goods sector, and 2) the production of tradable goods exhibits important externalities to productivity.

In terms of the externalities, I assume that innovation in new productivity-increasing technologies is driven by two sources: 1) “learning-by-doing” with respect to the share of labor employed in the production of tradable goods, and 2) the relative distance of domestic technical capabilities from a global technological frontier. Consumers and firms are too small to individually take into account the impacts of their consumption/employment decisions on the growth rate of new technology applied to production. Therefore, the optimal evolution of the economy can only be achieved by a “social planner” that is sufficiently omniscient to internalize the positive spillover effects of higher employment in the tradable sector when making his consumption decisions, or equivalently a government agent that can direct the level of employment by influencing private consumption decisions via appropriate policy. The government can exert such influence by implementing a number of policies, including equal import tariffs and export subsidies, taxation on consumption of tradable goods, and/or subsidization of the production of tradable goods. However, all of these options are considered to be infeasible for one or more of the following reasons: 1) special interests may preclude the use of optimal policy due to political opposition or the incursion of overly dear rent-seeking costs, 2) the government may be incapable of appropriately identifying which industries to subsidize/tax, and/or most importantly 3) such

price-based policies may be in violation of international agreements, such as WTO membership. The WTO, for example, rules out explicit import tariffs or export subsidies, in addition to production subsidies that may provide an “unfair” advantage in international market competition. These restrictions carry weight because of the WTO’s dispute resolution mechanism, which may authorize aggrieved parties to take countervailing actions.

I therefore assume that the government promotes exports through the use of capital controls, which do not face the same obstacles as price-based policies. That is, there exists no universal framework governing the international flows of capital in the same way that the WTO regulates the trade of physical goods among its member countries. Even the IMF, as the world’s largest overseer of the international monetary system, acknowledges in its Articles of Agreement the rights of its member countries to “exercise such controls as are necessary to regulate international capital movements.” While the IMF does have a history of advocating for greater liberalization of international capital markets, its most direct influence has been mostly restricted to a small set of economies in severe financial crises (e.g. Mexico, Thailand, and Argentina), and its own views have become more accommodative of capital controls in certain circumstances since the 2008 global financial crisis.²

The fundamental intuition underpinning the results of the model lies in the balance between the consumer’s desire to *increase* short-term tradable consumption by

²See IMF (2012).

borrowing against higher future output growth so as to smooth consumption over time and the desire to *decrease* short-term tradable consumption – thus increasing net foreign wealth – in order to fuel quicker output growth via faster convergence to the global technological frontier. This latter motivation is the rationale for mercantilist asset accumulation. The main takeaway from the results of the model is that the former desire for consumption smoothing is the dominant factor. In a sense, the consequence of the latter behavior – faster output growth – serves to intensify the motivation of the former behavior – consumption smoothing via borrowing. Thus, “mercantilist” asset accumulation is somewhat self-defeating, such that economies still desire to become net debtors to the rest of the world, even over a wide range of calibrations.

There have been two main bodies of work in the literature seeking to explain observed/optimal levels of foreign assets. First, several papers have proposed that stocks of assets be viewed as “war chests” of precautionary savings against risk, either at the household level in the case of idiosyncratic risk,³ or at the national level in the case of “sudden-stop” access to international credit.⁴ These papers have demonstrated mixed success in rationalizing the large reserve holdings of China.

A second body of work, which I categorize as “mercantilist,” has alternatively proposed that hoarding assets can be indirectly effectual in driving real economic growth. Dooley et al (2004) theorizes that asset accumulation is a byproduct of a

³See Carroll and Jeanne (2009) and Mendoza et al (2007)

⁴See Durdu et al (2009) and Jeanne and Ranciere (2011)

growth strategy that involves a developing periphery focusing on producing exports to take advantage of vast external demand from a rich core economy. While successful in popularizing a narrative of growth-promoting mercantilism, others have sought to expand on its premise by offering more rigorous mathematical foundations. A common theme among these models is an assumption that the tradable sector exhibits special characteristics that can be exploited in conjunction with asset accumulation to achieve positive real effects.

This chapter is related to a number of recent papers on mercantilist policy. Rodrik (2008) presents a simple model relating economic growth rates to market imperfections in the tradable-goods sector. This chapter improves on that work by presenting a more explicit model of the tradable sector’s inefficiency (in the form of an empirically-motivated production externality) and offering a full welfare analysis. Korinek and Serven (2010) also derive a model allowing a welfare analysis of mercantilist behavior, although this chapter differs in two important respects: 1) I assume the presence of learning-by-doing benefits to production as opposed to Romer-style learning-by-investing,⁵ and 2) this chapter importantly allows for an analysis of the optimal path of reserves over time, which is absent from the Korinek and Serven model due to the government effectively “throwing away” all foreign assets. Michaud and Rothert (2014) also offer a similar analysis of optimal government policy in the context of a small open economy with a learning-by-doing externality, albeit with-

⁵Aizenman and Lee (2007) discuss how different types of externalities can lead to significantly different policy recommendations.

out the influences of capital and investment, whose flows are important in trying to explain current account balances. This chapter differs by 1) including physical capital and investment in a multi-sector economy (which affect both the existence of real exchange rate dynamics and the size of welfare gains), 2) offering an empirical estimation of the technological frontier and the size of the growth externality, and 3) focusing on the capability of mercantilist policy to exhibit current account surpluses as observed in developing economies.

Other papers have also sought to explain the growth of developing economies concurrent with large current account surpluses by considering firms' access to liquidity within an economy. Song, Storesletten, and Zilibotti (2011) offer a model explaining the recent growth of China as a matter of resource allocation from low- to high-productivity firms, where growing firms' insufficient access to investment funds leads them to increase savings and generate a foreign surplus. Along these lines, Cheng (2012) presents a model with similar liquidity constraints that are overcome by the government actively intervening to provide domestic liquidity and investing the proceeds abroad. Similarly, Benigno and Fornaro (2014) consider the welfare effects of reserve accumulation in developing economies, using a technology externality that relies on the importation of intermediate goods, while also requiring firms to find sufficient financing to fund production activities. In contrast to the model presented in this chapter, they do not assume the existence of a technological frontier (resulting in permanent shifts in the rate of change of the exchange rate) and much of the welfare

gains in their model are driven by the government's role in helping firms overcome stochastic financial crises. This chapter instead offers a perfect foresight analysis of developing economies that focuses predominantly on the impact of mercantilist capital controls on welfare.

This chapter is also related to a few other strains of research. First, it is closely related to the literature noting the disconnect between the predictions of neoclassical models that capital ought to flow to those economies with high marginal products and actual empirical observations. Lucas (1990) first drew attention to the small amount of capital flowing into developing countries, and Prasad, et al (2007) further highlighted the fact the developing countries were actually exporting capital instead of importing. Gourinchas and Jeanne (2013) refer to this as the “allocation puzzle” and note the positive correlation between capital outflows and productivity growth.

Second, this chapter is influenced by endogenous growth models that rely upon dynamics in the level of technology/productivity or innovation, rather than capital deepening, to drive growth in the long-run, such as Helpman (1991), Aghion and Howitt (1992), and Eaton and Kortum (1999). Furthermore, the model draws upon the work of Grossman and Helpman (1991) and Melitz (2003), who demonstrate a link between technological adoption and exposure to international trade at the aggregate level,⁶ in assuming the presence of a positive externality to technological growth

⁶There also exists a large empirical literature examining the relationship between exporting and productivity at the firm level, although the findings are very mixed. Wagner (2007) provides a survey of this work. Park, et al (2010) and Ma and Zhang (2008) provide evidence of a positive relationship between exports and productivity in Chinese firms.

stemming from the tradable sector, which is most closely tied to international sources of innovation and inspiration.

Third, this chapter takes cues from the extensive work on technological convergence, or the “Veblen-Gerschenkron effect.”⁷ Among the first to propose dynamic mathematical models of catch-up to a “global frontier” were Nelson and Phelps (1966) and Findlay (1978), with Barro and Sala-i-Martin (1997), Howitt (2000), and Acemoglu et al (2006) providing more modern examples.⁸ Each paper proposes a different variable that affects the speed of convergence, including “educational attainment,” R&D expenditures, and managerial skill. I assume that technology converges to a global frontier at a rate that is determined by the level of employment in the tradable-goods sector, which can be interpreted as a “learning-by-doing” style of technological progress. This assumption provides a conceptual link between the economy’s dynamic growth and the consumption/saving decisions of the consumer.

Finally, this chapter is also marginally related to the literature on “Dutch disease,” in the sense that the reallocation of particular factors of production within the economy may have important effects on long-term growth.

This chapter is structured as follows. Section 1.1 presents the basic setup of the model and alternative options for government policy. Section 1.2 presents an empirical calibration of the model, and Section 1.3 discusses the results of a benchmark model

⁷Veblen (1915) and Gerschenkron (1952) were among the first economists to comment on the advantages of “relative backwardness” in catching-up to innovators.

⁸See Bernard and Jones (1996) and Kumar and Russell (2002) for a sample of the conflicting empirical evidence on technological convergence.

along with the robustness to alternative parameterizations. Section 1.4 provides a brief conclusion.

1.1 Model

1.1.1 Consumer Demand

I consider a small open economy comprising many identical, infinitely-lived consumers whose total population mass is normalized to unity. The economy permits a representative consumer who seeks to maximize his lifetime discounted utility, given by

$$U_0 = \int_0^\infty u[C_t]e^{-\rho t}dt, \quad (1.1)$$

where instantaneous utility is defined by a CRRA felicity function of the form $u[C_t] = C_t^{1-\theta}/(1-\theta)$, such that $1/\theta$ is the elasticity of intertemporal substitution, and ρ is the consumer's temporal discount rate. "Real consumption" C_t is a composite of two goods: an internationally tradable good and a domestically-consumed nontradable good (denoted by T and N , respectively). The real consumption index exhibits the following CES form

$$C_t = \tilde{C}[C_{Tt}, C_{Nt}] = \left(\phi C_{Tt}^{\frac{\sigma-1}{\sigma}} + (1-\phi) C_{Nt}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \quad (1.2)$$

such that σ measures the elasticity of substitution between tradable and nontradable goods.

In the baseline laissez-faire version of the model, the representative consumer earns income by owning and renting out units of capital to firms in exchange for rental income as well as inelastically providing labor to firms in exchange for wages. At every point in time, consumers make decisions on how best to allocate their income between consumption, investment in additional physical capital, and the purchase of interest-bearing foreign assets. Using tradable goods as the numeraire (such that their price is fixed at unity, i.e. $p_T \equiv 1$), the representative consumer's dynamic budget constraint can therefore be expressed in aggregate as

$$\dot{B}_t = r^* B_t + R_t K_t^d + W_t - \frac{1}{q_t} C_t - I_t^d, \quad (1.3)$$

where B_t represents the consumer's stock of foreign assets (a negative value implying foreign debt), r^* is the exogenously-determined fixed rate of interest on foreign assets, W_t is the wage rate, R_t is the rental rate of physical capital, K_t^d is the domestically-owned stock of physical capital, and I_t^d is domestic investment in new capital. q_t represents the relative price of tradables in terms of real consumption ($q_t = p_T/p_{Ct}$), which serves as the real exchange rate for the economy (an increase reflecting a real depreciation).

Additionally, the consumer is restricted in his dynamic consumption choices by

the following condition

$$\lim_{t \rightarrow \infty} B_t e^{-r^* t} \geq 0, \quad (1.4)$$

which rules out Ponzi-type borrowing schemes. If consumers are non-satiated, then this condition will generally hold with equality since it would be suboptimal to leave assets “on the table”. By contrast, Korinek and Serven (2010) requires consumers to abandon their claims on tradable assets in order to achieve the economy’s optimal dynamic path.

The economy is fully open to foreign direct investment, so that ownership of the aggregate capital stock is split between domestic and foreign agents,

$$K_t = K_t^d + K_t^f, \quad (1.5)$$

and new capital is created from tradable goods according to the following

$$\dot{K}_t = I_t - \delta K_t, \quad (1.6)$$

where aggregate investment (I_t) is the sum of domestic (I_t^d) and foreign investment (I_t^f), and δ is the rate of capital depreciation. When deriving the consumer’s intertemporal optimization conditions in the following sections, it will be useful to have a definition of total domestically-owned assets M_t , which is the sum of consumers’ claims on foreign assets B_t and domestically owned capital K_t^d . We can then define

net foreign assets⁹ as

$$NFA_t = B_t - K_t^f \quad (1.7)$$

$$= B_t - (K_t - K_t^d) \quad (1.8)$$

$$= M_t - K_t. \quad (1.9)$$

The representative consumer seeks to maximize his real consumption at every point in time by optimizing the mix of tradable and nontradable consumption subject to some allocated level of expenditures, resulting in the following intratemporal first-order conditions

$$\begin{aligned} p_{Ct} \cdot \frac{\partial C_t}{\partial C_{Nt}} &= p_{Nt} \\ \Rightarrow \quad p_t &= \frac{1-\phi}{\phi} \left(\frac{C_{Tt}}{C_{Nt}} \right)^{1/\sigma}, \\ p_{Ct} \cdot \frac{\partial C_t}{\partial C_{Tt}} &= p_T \end{aligned} \quad (1.10)$$

where $p_t = p_{Nt}/p_T$ is the price of nontradable goods in terms of tradable goods and p_{Ct} is the price of composite real consumption. Using the conditions in (1.10), the real exchange rate can be expressed as

$$q_t = \phi \left[\phi + (1 - \phi) \left(\frac{1-\phi}{\phi p_t} \right)^{\sigma-1} \right]^{\frac{1}{\sigma-1}}. \quad (1.11)$$

Thus, the economy's real exchange rate is a straightforward function of the relative

⁹The assumption of free FDI flows implies that the model only determines the total value of net foreign assets and not its individual components (i.e. what share of the capital stock is foreign-owned). Alternatively assuming that all physical capital is domestically owned would allow for an exact accounting of asset ownership without affecting any of the results.

price of nontradable goods.

1.1.2 Production

The supply side of the economy comprises numerous firms in two sectors producing tradable and nontradable goods using capital and labor. In aggregate, these sectoral outputs can be respectively expressed as

$$Y_{Tt} = K_{Tt}^\alpha (A_t L_{Tt})^{1-\alpha} \quad (1.12)$$

$$Y_{Nt} = K_{Nt}^\alpha (A_t L_{Nt})^{1-\alpha}, \quad (1.13)$$

where A_t represents the economy-wide level of labor-augmenting technology and/or productivity.¹⁰ The assumption of homogeneous factor output elasticities across sectors is made for mathematical simplicity and can easily be relaxed without major implications. Total output is measured as $Y_t = Y_{Tt} + p_t Y_{Nt}$. Firms choose their allocations of productive resources based on profit maximization, subject to the following constraints in aggregate

$$K_{Tt} + K_{Nt} = K_t \quad (1.14)$$

$$L_{Tt} + L_{Nt} = 1, \quad (1.15)$$

¹⁰Alternatively allowing for sector-specific levels of technology does have minor implications for the transition paths of economic variables in the model, but does not significantly impact the main results, so long as the tradable sector is assumed to exhibit greater productivity externalities than the nontradable sector.

where capital and labor are both freely mobile between domestic sectors.

Defining $\kappa_{\bullet t} \equiv K_{\bullet t}/L_{\bullet t}$ as the relative capital intensities employed in a sector, then factor mobility and profit maximization imply the following conditions for wages

$$(1 - \alpha)\kappa_{Tt}^\alpha A_t^{1-\alpha} = W_t \quad (1.16)$$

$$p_t(1 - \alpha)\kappa_{Nt}^\alpha A_t^{1-\alpha} = W_t, \quad (1.17)$$

and likewise for rental rates

$$\alpha\kappa_{Tt}^{\alpha-1} A_t^{1-\alpha} = R_t \quad (1.18)$$

$$p_t\alpha\kappa_{Nt}^{\alpha-1} A_t^{1-\alpha} = R_t. \quad (1.19)$$

Since foreign agents are free to invest in domestic capital or other international investments at the fixed rate of r^* , and because the international pool of investment funds is large relative to domestic financial flows, the economy exhibits internal parity with the international rate of interest, such that

$$R_t = r^* + \delta. \quad (1.20)$$

Since the international interest rate is taken as given, the supply side of the economy intratemporally determines the wage rate, relative factor intensities, and relative price of nontradables all independently of domestic demand, such that one can use the

conditions in (1.14) - (1.20) to express these variables as

$$\kappa_{Tt} = \kappa_{Nt} = \left(\frac{\alpha}{r^* + \delta}\right)^{1/(1-\alpha)} A_t \quad (1.21)$$

$$W_t = (1 - \alpha) \left(\frac{\alpha}{r^* + \delta}\right)^{\alpha/(1-\alpha)} A_t \equiv \bar{w} A_t \quad (1.22)$$

$$p_t = 1. \quad (1.23)$$

Thus, we can easily see by expressions (1.11) and (2.34) that both the relative price of nontradables and the real exchange rate are constant over time, i.e.

$$q_t = \phi \left[\phi + (1 - \phi) \left(\frac{1-\phi}{\phi} \right)^{\sigma-1} \right]^{\frac{1}{\sigma-1}} \equiv \bar{q}. \quad (1.24)$$

This is consistent with the well-known Harrod-Balassa-Samuelson effect, which predicts varying real exchange rates based on intersectoral productivity differentials. Since technologies have been assumed to be homogenous across sectors, the economy does not exhibit real exchange rate dynamics.¹¹

In accordance with Rodrik (2008), the final key assumption of the model is the presence of a learning-by-doing externality in the production of tradable goods, such that the evolution of technology over time is related to the endogenously-determined amount of labor employed in the tradable sector. Similar to Nelson and Phelps (1966), I assume that the aggregate measure of technology/efficiency in production

¹¹In other theoretical analyses of new mercantilism, exchange rate depreciation is often predicted as a side-effect of government policy. However, such depreciation is subordinate in importance to the reallocation of resources within the economy in terms of explaining higher rates of growth or levels of welfare. For examples, see Michaud and Rothert (2014) and Korinek and Serven (2010).

A_t generally exhibits the following rate of growth

$$\frac{\dot{A}_t}{A_t} = g \left[L_{Tt}, \frac{A_t^*}{A_t} \right], \quad (1.25)$$

where A_t^* denotes the world “frontier” level of technology, which grows at the exogenous rate of g^* . The intuition is that developing countries catch-up to the frontier A_t^* by absorbing previously pioneered expertise/know-how and instituting established best practices. The speed of convergence to the frontier is related to the size of the labor share in the tradable sector, since tradable production is by its nature intrinsically more directly connected to the wealth of international knowledge and having a greater number of employees exposed to the international competition fosters quicker domestic application. Thus, the function $g(\bullet)$ satisfies the following conditions:

$$\frac{\partial g}{\partial L_{Tt}} > 0 \quad (1.26)$$

$$\frac{\partial g}{\partial \left(\frac{A_t^*}{A_t} \right)} > 0 \quad (1.27)$$

$$g[L_{Tt}, f] = g^* \quad \forall L_{Tt} \in [0, 1], \quad (1.28)$$

where f represents the long-run level of technology to which the economy converges relative to the frontier. Assuming the economy begins with a lower level of technology such that $A_0 < A_0^*$, then the growth rate of domestic technology will converge to the frontier growth rate over time, by construction, and the speed of this convergence

can be improved by employing a larger share of labor in tradable production. However, institutional weaknesses that inhibit the absorption and implementation of new technologies may prohibit the economy from ever fully reaching the full *level* of the frontier at any point in time, though the economy may still converge to the same *rate* of technological growth g^* .

More specifically, I assume that the growth rate of technology takes on the following functional form

$$\frac{\dot{A}_t}{A_t} = g^* + \left(\gamma_0 + \gamma_1 L_{Tt} \right) \left(\frac{A_t^*}{A_t} - f \right), \quad (1.29)$$

which satisfies the conditions above so long as $\gamma_1 > 0$. Note that full convergence to the frontier is implied when $f = 1$, and incomplete long-term convergence occurs when $f > 1$.

1.1.3 Asset Accumulation Motive

Using the basic assumptions of the model, I now illustrate the potential motivation for accumulating foreign assets. This section essentially demonstrates the “mercantilist” aspect of the model, whereby the exportation of tradable goods is linked to higher transitional growth rates for the real economy.

First, using the relative price equilibrium in the economy defined by setting the demand-side pricing condition in (1.10) equal to the supply-side pricing condition in

(2.34) allows us to derive an expression linking nontradable and tradable consumption

$$C_{Nt} = \left(\frac{1-\phi}{\phi}\right)^\sigma \cdot C_{Tt} \equiv \bar{c}_N \cdot C_{Tt}. \quad (1.30)$$

Therefore, using the nontradability constraint $Y_{Nt} = C_{Nt}$, the output of the nontradable sector given by (2.4), the labor resource constraint in (1.15), the relative factor intensities in (1.21), and the tradable/nontradable consumption link above, we can derive the following relationship between the allocation of labor to the production of tradable goods and the consumption of tradable goods,

$$\begin{aligned} C_{Nt} &= K_{Nt}^\alpha (A_t L_{Nt})^{1-\alpha} \\ C_{Nt} &= (\kappa_{Nt} L_{Nt})^\alpha (A_t L_{Nt})^{1-\alpha} \\ C_{Nt} &= \kappa_{Nt}^\alpha A_t^{1-\alpha} (1 - L_{Tt}) \\ L_{Tt} &= 1 - \left(\frac{\alpha}{r^* + \delta}\right)^{\alpha/(\alpha-1)} \bar{c}_N \frac{C_{Tt}}{A_t} \equiv 1 - \gamma_2 \frac{C_{Tt}}{A_t}, \end{aligned} \quad (1.31)$$

where L_{Tt} and C_{Tt} have an inverse linear relationship.

Therefore, the contemporaneous effect of reducing tradable consumption is to drive more labor into the production of tradable goods, thereby increasing tradable output and expanding the country's trade balance ($Y_{Tt} - C_{Tt} - I_t^d$), which may be used to finance the purchase of foreign assets. If we consider the equivalence between the price ratio defined by demand in (1.10) and that defined by supply in (2.34), then

it's clear that a reduction in tradable consumption must be matched by a decline in nontradable consumption, and since nontradable output must be fully consumed domestically this can be achieved by redirecting labor from the nontradable sector into the tradable sector. Repressing domestic consumption, thus, leads to higher employment of labor in the tradable sector in equilibrium.

Because of the relationship between tradable and nontradable consumption expressed in (1.30), we can express the real consumption function in (1.2) as

$$C_t = \tilde{C}[C_{Tt}, C_{Nt}] = (\phi + (1 - \phi)\bar{c}_N^{(\sigma-1)/\sigma})^{\sigma/(\sigma-1)} \cdot C_{Tt} \equiv \bar{c} \cdot C_{Tt}, \quad (1.32)$$

meaning we can alternatively express the instantaneous utility function in (1.1) as

$$u[C_t] = \frac{\bar{c}^{1-\theta}}{1-\theta} \cdot C_{Tt}^{1-\theta}. \quad (1.33)$$

Therefore, a reduction in tradable consumption unambiguously reduces utility at any specific point in time, but by virtue of the redirection of labor toward the tradable sector and the externality from tradable labor employment presented in (1.25), it also speeds the growth in productivity and allows the economy to enjoy a higher level of output in the future than it otherwise would have experienced.¹² Once the

¹²The assumption of homogeneous technologies between sectors can be thought of as a “limiting” case in allowing for the greatest possible impact of the productivity externality on welfare. Alternatively restricting the effect of the externality to increasing the growth rate of technology employed solely in the tradable sector would mainly weaken the magnitude of the results without significantly changing their substance. So, in seeking to demonstrate the possibility of welfare-increasing mercantilist policy, I restrict my analysis to the use of the specification in (1.29), whereby the externality affects productivity in both sectors of the economy simultaneously. By comparison, Chinese pro-

domestic level of technology attains the frontier, however, the incentive to restrain consumption disappears and the economy may begin to consume the interest income from any accumulated assets without penalty. The key questions at consideration are whether the dynamic gains from resource reallocation offset the early losses from constrained consumption and how large any accompanying expansion in the country's net foreign asset position would be.

1.1.4 Intertemporal Optimality Conditions

Having presented the intratemporal relationships among the key variables of the model, I now consider the optimal intertemporal conditions. This section shows how dynamic optimization in a laissez-faire economy differs from that of a centrally-planned economy, wherein a benevolent social planner seeks to maximize the discounted lifetime utility of the country. The social planner is able to exploit the production externality in the tradable goods sector by choosing the optimal level of tradable consumption. Later, I show how a government agent can make use of mercantilist policy to replicate the social planner's choices.

In order to ensure that countries at the technological frontier exhibit a balanced growth path, I assume that the following relationship exists among the model parameters: productivity rates between agricultural and nonagricultural sectors have been roughly comparable over past decades (See Zhu (2012) for a full discussion).

eters

$$g^* = \frac{r^* - \rho}{\theta}. \quad (1.34)$$

Therefore, in order to simplify the exposition of the model's solutions, I henceforth normalize endogenous variables by the frontier level of technology, A_t^* , and denote these transformed variables by lower-case letters, e.g.

$$c_t \equiv \frac{C_t}{A_t^*}.$$

1.1.4.1 Laissez-faire

As stated previously, the representative consumer's goal is to maximize his lifetime discounted utility presented in (1.1) subject to the dynamic budget constraint in (1.3). Since the consumer can freely choose between investing tradable output in additional physical capital or a limitless supply of foreign assets, his chosen level of investment in domestic capital along with foreigners' FDI funds guarantee that the interest rate parity condition in (1.20) holds. Thus, the consumer is indifferent between investing in additional physical capital or accumulating additional foreign assets since both will guarantee a constant rate of return r^* in equilibrium. Therefore, in making his intertemporal consumption choices the consumer only cares about his total stock of total assets, defined in normalized terms as $m_t \equiv b_t + k_t^d$. Thus, we can express the

representative consumer's dynamic optimization problem as

$$\max_{c_t} \int_0^\infty \hat{u}[c_t] e^{-(r^*-g^*)t} dt \quad (1.35)$$

$$\text{s.t.} \quad \dot{m}_t = (r^* - g^*)m_t + w_t - \frac{1}{q_t}c_t, \quad (1.36)$$

where the consumer takes prices and technology as given, and $\hat{u}[\bullet]$ is the normalized version of the instantaneous utility function in (1.1).

Optimizing with respect to consumption yields the following important first-order condition

$$\lambda = \frac{\partial \hat{u}}{\partial c_t} \cdot q_t = \frac{\partial \hat{u}}{\partial c_{Tt}}, \quad (1.37)$$

where λ is a constant co-state variable associated with total assets. This condition implies that the marginal utility of normalized tradable consumption must be time invariant. Therefore, (1.37) dictates that the optimal paths of real consumption, tradable consumption, and nontradable consumption will all be constant over time.

We can utilize the relationship between tradable labor and consumption in (1.31) to express the transition of technology from (1.29) in reduced form as

$$\dot{a}_t = \tilde{g}[a_t, c_{Tt}]. \quad (1.38)$$

Therefore, assuming the consumer has rational expectations, the dynamic equilibrium of the economy can be found by solving for the value of λ that defines the level of

tradable consumption in (1.37) and the path of technology in (1.38) such that the following intertemporal budget constraint is satisfied:

$$b_0 + k_0^d = - \int_0^\infty (\bar{w}a_t - \frac{\bar{c}}{q}c_{Tt})e^{-(r^*-g^*)t}dt, \quad (1.39)$$

where initial values of capital k_0^d and foreign assets b_0 are given and the right-hand side is solely a function of a_t and c_{Tt} . See the appendix for a full derivation of this constraint, as well as a description of the numerical solution methodology utilized.

1.1.4.2 Social Planner

I now consider the case of a benevolent social planner, who maximizes the lifetime discounted utility in (1.1) by explicitly choosing the path of tradable consumption C_{Tt} while taking the previously presented intratemporal equilibrium conditions as given. I assume that the social planner targets consumption instead of the level of employment in the tradable sector directly because of the consistency of this approach with the use of capital controls (discussed further in the following section). The social planner is assumed to be capable of recognizing the impacts of his choice of consumption on other aggregate variables in the economy, including the effects on intratemporal equilibrium prices and the growth rate of technology. As such, the social planner chooses the path for tradable consumption so as to indirectly exploit its inverse relationship with tradable-sector labor employment and achieve a more

optimal rate of technological advancement.

Using the pricing conditions in (1.10) and (2.34) to remove w_t and q_t from the dynamic budget constraint, the social planner's problem can be stated as

$$\max_{c_{Tt}} \int_0^\infty \tilde{u}[c_{Tt}] e^{-(r^*-g^*)t} dt \quad (1.40)$$

$$\text{s.t.} \quad \dot{m} = (r^* - g^*)m + \bar{w}a_t - \frac{\bar{c}}{\bar{q}}c_{Tt} \quad (1.41)$$

$$\dot{a}_t = \tilde{g}[a_t, c_{Tt}], \quad (1.42)$$

where the transition equation for technology is the reduced-form version from (1.38), and $\tilde{u}(\bullet)$ is the normalized version of the utility function from (1.33) expressed solely as a function of tradable consumption.

Optimization with respect to c_{Tt} yields the following first-order condition

$$\frac{\partial \tilde{u}}{\partial c_{Tt}} = -\frac{\partial \tilde{g}}{\partial c_{Tt}} \mu_t + \frac{\bar{c}}{\bar{q}} \lambda, \quad (1.43)$$

where λ is again the constant co-state variable associated with total assets, and μ_t is the co-state variable associated with technology. Furthermore, the first-order optimality condition with respect to technology yields the following expression for the evolution of μ_t

$$\dot{\mu}_t = \left[(r^* - g^*) - \frac{\partial \tilde{g}}{\partial a_t} \right] \mu_t - \bar{w} \lambda. \quad (1.44)$$

Because of the inverse relationship between labor employed in the tradable sector

and tradable consumption, as well as the assumption regarding the effect of L_{Tt} on technology growth in (1.26), we know that $\frac{\partial \tilde{g}}{\partial c_{Tt}} < 0$. Therefore, the right-hand side of (1.43) represents the marginal utility of tradable consumption, which is no longer constant (as in the laissez-faire setting) due to the variability in μ_t . Using the assumed form of the technology growth function in (1.29), we can also express marginal utility with respect to tradable consumption as

$$\frac{\partial \tilde{u}}{\partial c_{Tt}} = \frac{\bar{c}}{\bar{q}} \lambda + \gamma_1 \gamma_2 \left(\frac{1}{a_t} - f \right) \mu_t. \quad (1.45)$$

Since a_t converges to $1/f$ from below by construction and (1.44) implies that μ_t is bounded in the long-run steady-state, then it follows that

$$\lim_{t \rightarrow \infty} \frac{\partial \tilde{u}}{\partial c_{Tt}} = \frac{\bar{c}}{\bar{q}} \lambda. \quad (1.46)$$

Therefore, because μ_t is positive, equation (1.46) implies that the marginal utility of tradable consumption in the long-run is less than the marginal utility at every previous point in time, or equivalently

$$\lim_{t \rightarrow \infty} c_{Tt} > c_{Tt} \forall t, \quad (1.47)$$

that is, tradable consumption reaches its all time zenith in the long-run steady-state.

How does this compare to the laissez-faire solution? The fact that tradable con-

sumption must increase over time in the social planner's solution implies that its level must fall below that of the laissez-faire consumer's fixed consumption at some point in time, since both versions of the economy face the same intertemporal budget constraint. Intuitively, this lower level of consumption is likely to occur early on when the relative benefits to technological accumulation are the highest. In this sense, the mercantilist approach to optimal growth is characterized by an initial period of repressed consumption, which corresponds to a relatively larger net trade balance that could be used to finance the purchase of foreign assets.

Equation (1.44) together with (1.43) and the equations of motion for assets in (1.41) and technology in (1.42) define a three-dimensional system of differential equations that can be solved for the welfare maximizing path of tradable consumption in conjunction with the intertemporal budget constraint in (1.39). A detailed description of the numerical solution procedure employed is presented in the appendix.

1.1.5 Government Policy

Since the gains to technological innovation from labor employed in the tradable sector only arise at the aggregate level, individual consumers and firms are unable to identify and exploit the potential dynamic gains from reallocating resources within the economy. Assuming the government is large enough to internalize the importance of the externality and has the maximization of consumer welfare as its primary objective, then it can play an important role by influencing the relative levels of sectoral activity

in the economy in order to achieve a superior development path.

I first consider the use of capital controls and show how the government can use them to implement the social planner's optimal consumption path. Next, I consider various price-based policies that would provide first-best outcomes, but are nonetheless infeasible for reasons discussed below.

1.1.5.1 Capital Controls

Suppose the economy includes a government agent who interacts with the consumer via lump-sum transfer payments and/or the issue of domestic bonds, which are unavailable to foreign investors. I assume that the government controls the entire stock of domestic capital and consumers are restricted from investment and ownership.¹³ Additionally, the government institutes policies restricting individual consumers from buying or selling assets in the international market (forcing $b_t = 0$ for all t). Therefore, the representative consumer's dynamic budget constraint becomes

$$\dot{d}_t = (r_t^d - g^*)d_t + w_t - \frac{1}{q_t}c_t + z_t, \quad (1.48)$$

where d_t represents the consumer's stock of government-issued bonds, r_t^d is the rate of return on such bonds, and z_t represents tradable-goods-denominated net-transfer

¹³Alternatively allowing consumers to continue exclusively owning capital does not affect any of the results, but allows us to rule out the unrealistic scenario in which consumers sell off the entire stock of domestic capital to foreign investors. Assuming that domestic capital and investment decisions are under the government's purview is fairly realistic in the case of China, where the four largest banks are state-owned and control over 70% of the economy's financial assets (see Shih, Zhang, and Liu (2007)).

payments from the government (a negative value denoting a net tax). The government uses any revenue it collects to accumulate its own stock of foreign assets, such that its budget constraint can be expressed as

$$\dot{b}_t^G + z_t + i_t^d + (r_t^d - g^*)d_t = (r^* - g^*)b_t^G + \dot{d}_t + R_t k_t^d, \quad (1.49)$$

where b_t^G represents official government reserves of foreign assets. I also assume that the government is subject to a no-Ponzi-type borrowing constraint, parallel to that of the consumer's in (1.4), and the economy is still open to foreign direct investment in capital (similar to the Chinese experience of large FDI inflows in conjunction with tight capital controls), such that the interest parity condition in (1.20) still holds. Combining these constraints, along with the equation of motion for capital in (1.6), yields the following consolidated dynamic budget constraint for the whole economy

$$\dot{b}_t^G = (r^* - g^*)b_t^G + (R_t - g^*)k_t^d + w_t - \frac{1}{q_t}c_t - i_t^d, \quad (1.50)$$

which is nearly equivalent to the representative consumer's budget constraint in (1.3), with the important difference that the foreign assets are now solely under the control of the government.

To emphasize why this is important, one can use the intratemporal equilibrium pricing conditions in (1.22) and (1.24) and the interest parity condition in (1.20) to

rewrite the consolidated constraint as

$$\left(\dot{b}_t^G - (r^* - g^*)b_t^G + i_t^d\right) + (r^* + \delta - g^*)k_t^f = \tilde{y}_T[c_{Tt}, a_t] - c_{Tt}, \quad (1.51)$$

where $\tilde{y}_T[c_{Tt}, a_t] \equiv \left(\frac{\alpha}{r^* + \delta}\right)^{\frac{\alpha}{1-\alpha}} a_t - \left(\frac{1-\phi}{\phi}\right)^\sigma c_{Tt}$. Notice that all of the terms in the first set of parentheses on the left-hand side are under the government's control and the right-hand side can be expressed solely as a function of c_{Tt} and the state variable a_t .

Therefore, by taking the foreign-owned stock of capital and the level of technology as given and by virtue of the restrictions on private capital flows and its control over the economy's stock of foreign assets, the government is able to precisely determine the consumer's consumption path and thereby implement the social planner's optimal outcome. In other words, the government can induce "forced saving" on the part of the consumer (via tax transfers invested in foreign assets) in order to achieve a welfare-maximizing path for private consumption after internalizing the extant productivity externality in the tradable goods sector that consumers and firms are too small to individually recognize. Note that if the economy enters a long-run steady state in which the government's holdings of private assets are positive, then (1.49) implies that the government can distribute the flows of interest income back to domestic consumers (a feature not possible in the Korinek and Serven (2010) model).

1.1.5.2 First-Best Policy Interventions

As an alternative to the use of capital controls, the government's first-best option would be to use some kind of price-based policy to directly target the source of the dynamic inefficiency: employment in the tradable sector. Suppose that firms producing tradable output receive an ad valorem subsidy of $s_t \geq 0$ from the government for wages paid to labor (i.e. the subsidy reduces the labor costs faced by firms in the tradable sector), and this subsidy is financed via transfers from consumers so as to be revenue-neutral. Then the intratemporal profit-maximizing condition in (1.16) becomes

$$(1 - \alpha)\kappa_{Tt}^\alpha A_t^{1-\alpha} = W_t(1 - s_t), \quad (1.52)$$

which implies that the supply-side equilibrium pricing condition from (2.34) becomes

$$p_t = \left(\frac{1}{1 - s_t} \right)^{1-\alpha}. \quad (1.53)$$

Therefore, government policy has the effect of altering relative prices in the economy, which affords greater flexibility in reallocating resources and maintaining a high level of consumption as compared to the use of capital controls. To see this, note that after the introduction of a subsidy the level of tradable sector employment can be expressed as

$$L_{Tt} = 1 - (1 - s_t)^{\sigma-\alpha(\sigma-1)} \gamma_2 \frac{c_{Tt}}{a_t}, \quad (1.54)$$

which is identical to the expression in (1.31) when $s_t = 0$. Suppose the government wants to achieve a particular “high” target level of \hat{L}_T in order to speed technological growth. Under a capital control regime and the intratemporal equilibrium conditions in Sections 1.1.1 - 1.1.3, this would necessitate a specific level of tradable consumption \hat{c}_T and, in turn, a specific corresponding level of real consumption \hat{c} . However, by introducing a subsidy (such that $s > 0$), the government could achieve the same employment target \hat{L}_T with a level of consumption *higher* than \hat{c} because of the shift in relative prices.

In other words, the government is able to induce an equivalent degree of labor reallocation to the tradable sector over the short-run without needing to sacrifice as much consumption. Of course, the higher level of short-run consumption necessitates a higher level of borrowing relative to the case of capital controls (because of the inability to import nontradable goods), and therefore higher interest payments and lower long-term consumption. But these costs are offset by the relative welfare gains from having that higher consumption over the short-run, resulting in a net welfare gain relative to the use of capital controls. Thus, the government can achieve the first-best optimal outcome for the economy by choosing the appropriate path of $\{s_t\}_0^\infty$ over time.¹⁴

In such an economy, the use of a production subsidy is functionally equivalent to the implementation of an ad valorem tax on the consumption of tradable goods, a

¹⁴A full numerical analysis of the implementation of a first-best subsidy is available from the author by request.

subsidy on the production of tradable output, a tax on foreign borrowing, and/or the combined introduction of equivalent export subsidies and import tariffs. However, despite the ability of all of these policies to provide first-best outcomes, I assume that such policies are not feasible for a variety of reasons, including the well-known problems of targeting and/or rent-seeking costs. As discussed in the introduction, the most likely obstruction to the use of such policies is an obligation to adhere to regulations established by an international organization, such as the WTO. For example, a consumption tax would likely violate the Agreement on Implementation of Article VI of the GATT 1994, which states

“A product is to be considered as being dumped...if the export price of the product exported...is less than the comparable price...for the like product when [consumed] in the exporting country.”

Similarly, certain forms of direct subsidization of export-competing industries may be forbidden, as well as tariffs on imports.

On the other side, the IMF requires adherence to certain principles regarding the use of capital controls, although the degree to which any country’s policies stand in violation is often open to interpretation. More importantly, and unlike the WTO, the IMF lacks an active conflict resolution body to adjudicate any alleged violations. Therefore, the government of a developing economy may direct the path of tradable consumption without violating any multinational trade agreements by employing strict controls on the flows of private financial capital. Therefore, for the remainder of the chapter, I focus on the results of government implementation of

capital controls as a second-best alternative policy approach to improving welfare via strict bans on private international borrowing and lending.

1.2 Calibration

In order to fully understand the effects of government policy on the economy, we need to have a realistic idea of the size of the externality to technology in the tradable goods sector. In this section, I use cross-country panel data to empirically estimate a plausible range of values for the parameters in the technological growth equation in (1.29), which drives the possibility of welfare gains via mercantilist policy.

Due to the assumption of homogeneous technologies and factor income shares across the two sectors of production in the economy, the production functions in (2.5) and (2.4) can be combined to derive the following consolidated production function for aggregate output

$$Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}, \quad (1.55)$$

where the size of the aggregate supply of labor L_t is generalized for values other than unity. By using observations of an economy's total aggregate output, capital stock, and labor force, it's possible to calculate residual estimates of the overall technology level A_t .

I use data from the World Bank's *World Development Indicators* (WDI) for the size of the economy's labor force (adult population, ages 15-64) and the *Penn-World*

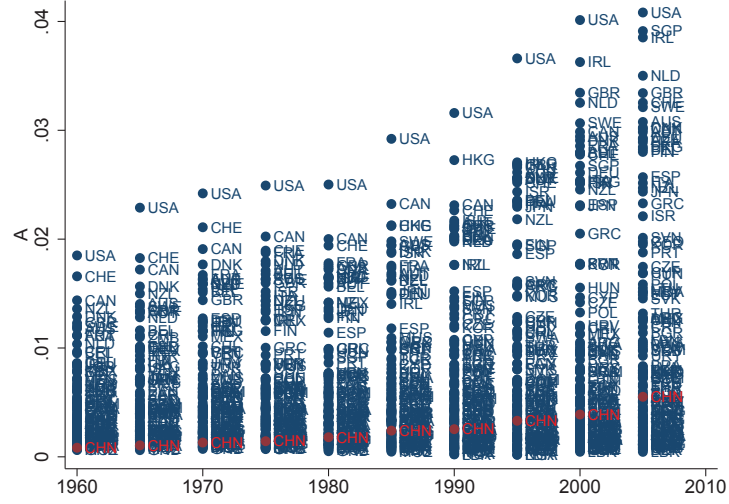


Figure 1.1: Distribution of residual technology A_t estimates.

Tables 8.0 (PWT)¹⁵ for PPP-converted real GDP measures. I follow the development accounting literature's standard of assuming a constant capital share of income of $\alpha = 1/3$. I also use country-level data on capital transformation shares of GDP from the PWT to estimate national aggregate capital stocks using a perpetual inventory method, assuming a depreciation rate of 6%. I then back out residual values for technology over the period 1960-2009 for 125 countries,¹⁶ the distributions of which are presented in Figure 1.3. Observations for each time period are averages over five-year intervals in order to reduce transitory noise and focus on fundamentals-based long-term trends.

I define the technology frontier A_t^* as the highest value of technology out of all

¹⁵Feenstra, Inklaar, and Timmer (2013).

¹⁶I follow Bernanke and Gurkaynak (2001) and Mankiw, Romer, and Weil (1992) in excluding economies whose GDPs rely predominately on oil production and economies with populations of less than one million.

countries in the sample in each period, which happens to correspond to the United States in every five-year average period. Individual countries' (indexed by i) technology growth rates are calculated as the log changes from period $t - 1$ to t and then subtracted from the growth rate of the frontier g_t^* to create a measure of a country's "growth premium." I use data on the share of the labor force engaged in industrial production (also from the WDI) as a proxy for tradable-sector employment L_{Tt} , and the ratio of A_{t-1}^*/A_{t-1} as a measure of a country's technological distance from the frontier. Summary statistics for the data over the period 1980-2009¹⁷ are presented in Table 1.1.

Variable	Mean	Std Dev	Min	Max
$\Delta \log A_{t,i} - g_t^*$	-.002	.048	-.275	.291
$L_{Tt-1,i}$	.245	.088	.023	.471
$\frac{A_{t-1}^*}{A_{t-1,i}}$	7.08	8.36	1	56
law_i	56.9	27.5	3.5	100
$politic_i$	67.7	22.0	10	100

Table 1.1: Calibration data summary statistics

Using these data, I estimate the parameters of the technological growth equation in (1.29) using two different regression equations. First, I consider the following:

$$\Delta \log A_{t,i} - g_t^* = \left(\gamma_0 + \gamma_1 \cdot L_{Tt-1,i} \right) \left(\frac{A_{t-1}^*}{A_{t-1,i}} - (1 + e^h) \right) + \epsilon_{t,i}, \quad (1.56)$$

¹⁷WDI data on shares of labor in industrial output begin in 1980.

where $\epsilon_{t,i}$ is an error term and estimates of h generate values of f (the degree of convergence to the frontier) that are restricted by construction from being greater than one.¹⁸ I estimate values for γ_0 , γ_1 , and h using nonlinear least squares and “cluster-robust” standard errors, which allow for correlation across each country’s error terms. Results are presented in column (1) of Table 1.2. The estimated value of $\hat{h} = -33.84$ implies a common cross-country value of $f = 1$, signifying perfect convergence to the technological frontier.

Alternatively, each country may actually only converge in the long-run to an individual fraction of the global frontier, similar to Howitt (2000). However, estimating such country-specific differences in long-run technological capabilities is problematic, as it requires the identification of certain prescient characteristics that vary across countries. In considering cross-country differences in productivity, Hall and Jones (1999) suggest that these idiosyncrasies may be best explained by variance in “social infrastructure,” such as institutional quality and government policy. In the current context, we must suppose that countries exhibit differences in social infrastructure that are both influential to an economy’s technological progress but also extremely resistant to dynamic change, so as to be credible in forecasting long-term future conditions. Thus, I attempt to estimate reasonable country-specific values of f using the

¹⁸Note that this restriction does not necessarily imply that other countries are incapable of surpassing the productivity of the US in the future or that the US will always be the global technological leader.

following:

$$\Delta \log A_{t,i} - g_t^* = \left(\gamma_0 + \gamma_1 \cdot L_{Tt-1,i} \right) \left(\frac{A_{t-1}^*}{A_{t-1,i}} - \left(\min_t \frac{A_t^*}{A_{ti}} + \left(\frac{e^{\psi_0 + \psi_1 law_i + \psi_2 politic_i}}{1 + e^{\psi_0 + \psi_1 law_i + \psi_2 politic_i}} \right) \left(1 - \min_t \frac{A_t^*}{A_{ti}} \right) \right) \right) + \nu_t \quad (1.57)$$

where $\nu_{t,i}$ is another error term, and the additional covariates represent indices of a country's "rule of law" and "political stability" from the Global Innovation Index (Cornell, INSEAD, and WIPO (2013)), which arguably both affect technological absorption (by way of the risks and rewards associated with investment into research and adoption of new production methods) and are very slow to change over time.

I estimate the values of the parameters γ_0 , γ_1 , ψ_0 , ψ_1 , ψ_2 again using nonlinear least squares and cluster-robust standard errors. The functional form ensures that estimates of f will fall between one (implying full convergence) and the minimum distance from the frontier actually already observed for each country (precluding the possibility of retrogradation). Estimation results are presented in column (2) of Table 1.2. Implied estimates of the value of f_i (using the estimated values of ψ_0 , ψ_1 , ψ_2 , and country-specific observed values of law_i and $politic_i$) for a small sample of countries are presented in Table 1.3. The correlation between the average of law_i and $politic_i$ for each country and the associated estimate of f is -0.6 , suggesting that stronger governance enables countries to more closely approach the global technological frontier in the long-run.

	Specification	
$\Delta \log A_{t,i} - g_t^*$	(1)	(2)
$\hat{\gamma}_0$	−.0005 (.0005) [−.0014, .0004]	−.0007 (.0007) [−.0021, .0007]
$\hat{\gamma}_1$	.0050 (.0031) [−.0011, .0111]	.0111** (.0045) [.0021, .0200]
\hat{h}	−33.84	—
$\hat{\psi}_0$	—	−1015
$\hat{\psi}_1$	—	3.265
$\hat{\psi}_2$	—	11.41
R^2	.0129	.0352
n	363	352

Table 1.2: Nonlinear least squares estimation results of regression of A_t growth premium on distance from the technological frontier, and industrial labor share. Standard errors are reported in parenthesis, and 95% confidence intervals in brackets. ** signifies statistical significance at the 5% level.

Unfortunately, finding accurate estimates of the country-specific f parameters is very difficult, since there is effectively only one observation per country, and using even the most recent measures of the “rule of law” and “political stability” covariates may be a poor estimate of what the long-run characteristics of a given country might be some 100 years in the future. Moreover, the estimation presented here sidesteps some obvious issues with endogeneity, as higher future incomes may enable countries to improve their ability to govern effectively over time. At the very least, the estimates

in Tables 1.2 and 1.3 give proximity estimates of reasonable values for the relevant parameters, and in later sections I consider the effects of varying these estimates over wide ranges.

Country	\hat{f}_i
United States	1
China	7.4
Germany	1
Brazil	3.6
United Kingdom	1
Greece	1.8
South Korea	1
Mali	17
Thailand	5.5
El Salvador	12.6

Table 1.3: Sample of estimated values of f using equation (1.57).

In considering a benchmark parameterization for the model, it is illustrative to look at the specific case of China, as it is the largest individual holder of foreign reserves in the world and a commonly cited example of “mercantilist” behavior in recent years. I calibrate the model to match the characteristics of China in the year 2000, shortly before its accession to the WTO and its subsequent decade of high growth and massive foreign asset accumulation. In this specific case of China in the year 2000, the estimates from Specification (2) in Table 1.2 suggest that a 10 percentage point increase in the share of labor employed in the tradable sector

would increase the growth rate of technology by approximately 0.4 percentage points using the estimate of f in Table 1.3 and up to 1.1 percentage points assuming full technological convergence (such that $f = 1$). Though this is a substantial effect, it is even considerably less than the one-to-one estimated relationship between industrial labor shares and GDP growth rates in Rodrik (2008), which makes use of a number of additional covariates in a two-stage least squares regression.

For the benchmark results presented in the next section, I choose values of γ_0 and γ_1 that lie within their estimated 95% confidence intervals and correspond to an initial rate of economic growth that matches the average rate experienced by China of 9% over the 2000-2007 period. With regards to other model parameters, I choose values for r^* , ρ , and θ from standard value ranges so as to equate the technological growth rate, g^* , to the average growth rate of the technology frontier over the 1980-2009 period of about 1.8%. Tradable and nontradable goods are assumed to be complementary, such that their elasticity of substitution is less than one.¹⁹ The initial level of technology A_0 is set to the estimated level of technology in China in 2000 normalized by the estimated level of the frontier in the same period. I also assume that the economy's initial net foreign asset position has been normalized to zero and that the initial stock of physical capital equalizes the marginal product of capital with the international rate of interest (based on the initial level of domestic technology). Since the standard errors for the parameters involved in the estimation of f are

¹⁹See Kravis and Lipsey(1987) and Mendoza (1995) for empirical evidence.

extremely large, I start by assuming the most intuitive case of full convergence to the technological frontier ($f = 1$) in the benchmark model before considering alternative values. The chosen values for all parameters are shown in Table 2.1.

g^*	.018	Estimated
r^*	0.05	Calibrated to g^*
ρ	.02	Calibrated to g^*
θ	1.67	Calibrated to g^*
ϕ	0.3	Mendoza (1995)
σ	0.5	Mendoza (1995)
α	0.33	Standard
δ	.06	Standard
B_0	0	Normalized
A_0	1	Normalized
A_0^*	10	US relative to China in 2000
γ_0	0	China 9% growth
γ_1	.0197	China 9% growth
f	1	Estimated

Table 1.4: Chosen parameter values.

1.3 Results

This section presents the optimal paths of the economy's key variables in both a laissez-faire setting and in the presence of government intervention, which takes the form of capital controls coupled with taxes/transfer payments. I first develop

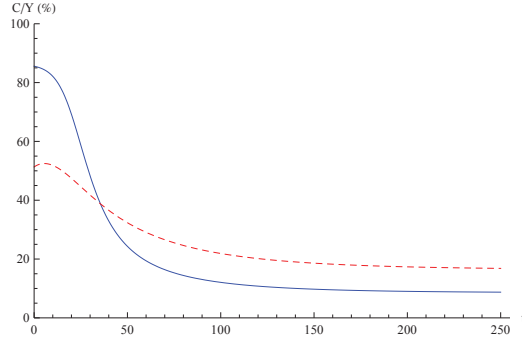


Figure 1.2: Paths of consumption under laissez-faire (solid) and capital controls (dashed) as % of total output.

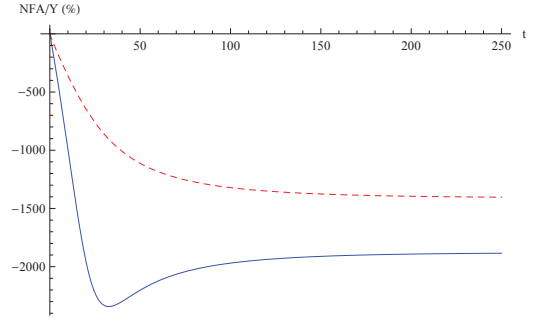


Figure 1.3: Paths of net foreign assets under laissez-faire (solid) and capital controls (dashed) as % of total output.

the intuition behind the results of a “benchmark” model using the chosen parameter values from the previous section and then consider the robustness of the results to alternative parameterizations.

1.3.1 Benchmark

The solutions to the utility-maximizing time paths of the economies’ aggregate variables using the parameter values in Table 2.1 are presented in Figures 1.4 - 1.11, where solid lines represent a laissez-faire economy and dashed lines represent an economy under capital controls. In order to fully understand the impact of government intervention, it’s informative to first consider the evolution of a laissez-faire economy.

The consumption decisions made by the representative consumer in a laissez-faire setting are very different from those induced by the government under capital controls, since the laissez-faire consumer only anticipates the growth in technology (because of the assumption of rational expectations) but does not internalize the effect of

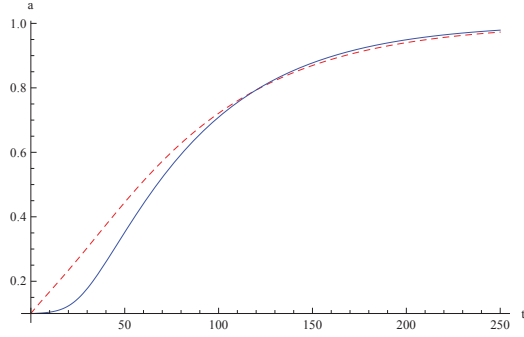


Figure 1.4: Paths of normalized technology under laissez-faire (solid) and capital controls (dashed).

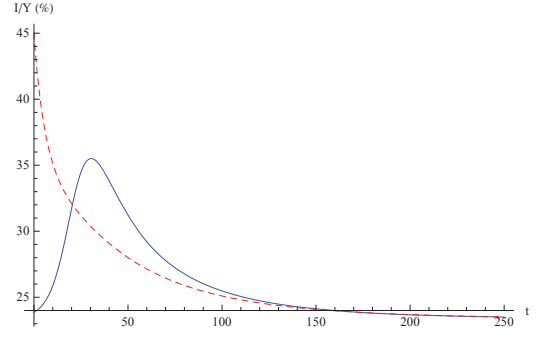


Figure 1.5: Paths of investment under laissez-faire (solid) and capital controls (dashed) as % of total output.

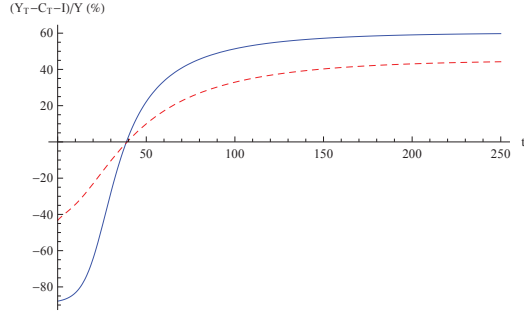


Figure 1.6: Paths of trade balances under laissez-faire (solid) and capital controls (dashed) as % of total output.

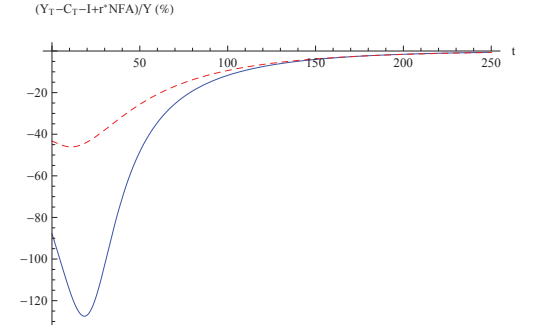


Figure 1.7: Paths of current accounts under laissez-faire (solid) and capital controls (dashed) as % of total output.

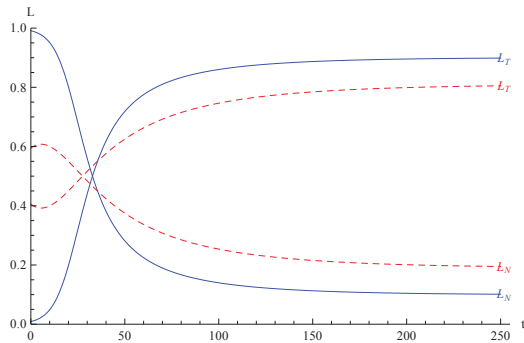


Figure 1.8: Paths of labor shares under laissez-faire (solid) and capital controls (dashed).

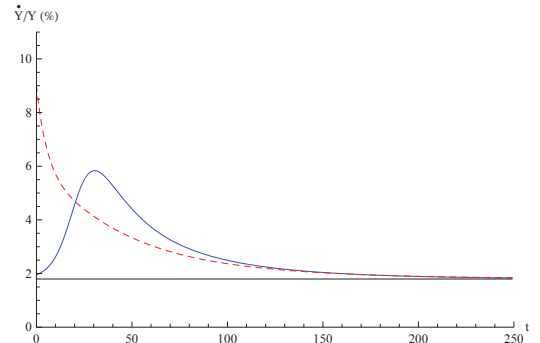


Figure 1.9: Paths of output growth rates under laissez-faire (solid) and capital controls (dashed).

his consumption on technological growth. In other words, because the laissez-faire consumer expects output to continually grow over the foreseeable future, he has a strong desire to borrow in the short-run against that future income stream in order to smooth his consumption profile over time. By definition, the economy can only import tradable goods to facilitate levels of consumption above its current productive capabilities. Therefore, the laissez-faire economy directs all of its productive resources into the nontradable sector, since tradable and nontradable goods are complementary and the desired short-run level of tradable consumption can all be imported.

Thus, the laissez-faire economy initially exhibits very low growth, since little labor is allocated to the tradable sector, which is the key stimulus to the advancement of technology. Eventually, however, the economy reaches a point at which it will no longer be able to continue borrowing all of its tradable consumption and still have sufficient resources available to avoid defaulting on its mounting debt. At such a time, the economy goes through a radical transformation as the allocations of labor between sectors are nearly fully reversed, such that production is almost entirely focused on tradable output. As seen in Figures 1.8 and 1.9, the economy switches from being a net importer to a net exporter with the exports going to pay off the interest on its accumulated debt. This transformation also causes a large spike in the growth rate as the labor being channeled into the tradable sector to provide the output for interest payments also contributes to a take-off in the absorption of new technologies. The higher levels of technology stemming from the tradable sector also spillover into

the nontradable sector, such that the economy is still able to produce an adequate level of nontradable consumption despite a much lower allocation of labor to that sector. Overall, the laissez-faire consumer has no motivation to run a positive current account balance.

In contrast, the government explicitly takes into account the impact of allocating labor to the tradable sector, as defined by (1.25), and accordingly guides the economy through a very different transition. The central story is illustrated by the paths of consumption in Figure 1.4. Initially, the levels of technology, and therefore total output, are equivalent between the two versions of the economy, but consumption is lower under capital controls than it is without. This is by virtue of the fact that the government is able to see the long-run dynamic effects of consumption on the implementation of advanced technologies and therefore intervenes in order to allocate a higher initial level of labor to the production of tradable goods, as seen in Figure 1.10. The benefit of this lower consumption is apparent in the faster rate of convergence to the technological frontier relative to the laissez-faire economy, shown in Figure 1.6. Even though the levels of technology both converge to the same level in the long-run, faster convergence to the frontier means the production of additional consumable output during the transition phase that would otherwise not be available. Furthermore, the higher levels of technology demand higher levels of capital to maintain international interest rate parity and satisfaction of the intratemporal profit-maximization conditions, such that aggregate investment is initially higher under capital controls

than in the laissez-faire setting.

The most interesting insight gained from the model is provided by the level of net foreign assets presented in Figure 1.5. As discussed above, the laissez-faire consumer is clearly motivated to run up a massive level of debt in order to finance a higher level of initial consumption. However, the intuition behind the outcome under government intervention is more complicated. There are essentially two opposing forces at work in determining the optimal level of assets. First, there is a desire to smooth consumption over time, as given by the elasticity of intertemporal substitution (EIS) and represented in the model by $1/\theta$. Second, there is a desire to boost the rate of technological growth, as represented by γ_1 . The reason these two motives work in opposition is because of the inverse relationship between tradable consumption and tradable-sector employment demonstrated in (1.31). On the one hand, the curvature of the instantaneous utility function implies that consumers maximize their welfare by borrowing from abroad in the short-term in order to finance *higher* initial consumption. On the other hand, the fact that allocating more labor to the tradable sector facilitates higher levels of tradable consumption in the future because of higher productivity implies that consumers can increase their welfare by enduring *lower* consumption in the short-run.

Ultimately, the mercantilist motivation to accumulate assets in order to achieve faster growth is self-defeating, in the sense that the more the government intervenes to reallocate additional labor to the tradable sector the more consumers want to bor-

row against the higher resulting future output to smooth their consumption. For the chosen calibration of parameters presented in Table 2.1, it turns out that the consumption smoothing motive dominates the asset accumulation motive, such that the optimal level of net foreign assets under government intervention is also negative. However, the quantity of assets borrowed under government intervention is less than under laissez-faire, meaning the economy does not need to export as much of its tradable output to cover interest payments. Ultimately, the short-term suppression of consumption pays off in higher output during the period of convergence to the technological frontier, resulting in a welfare gain of about 20% of permanent consumption under government intervention relative to the laissez-faire economy.²⁰

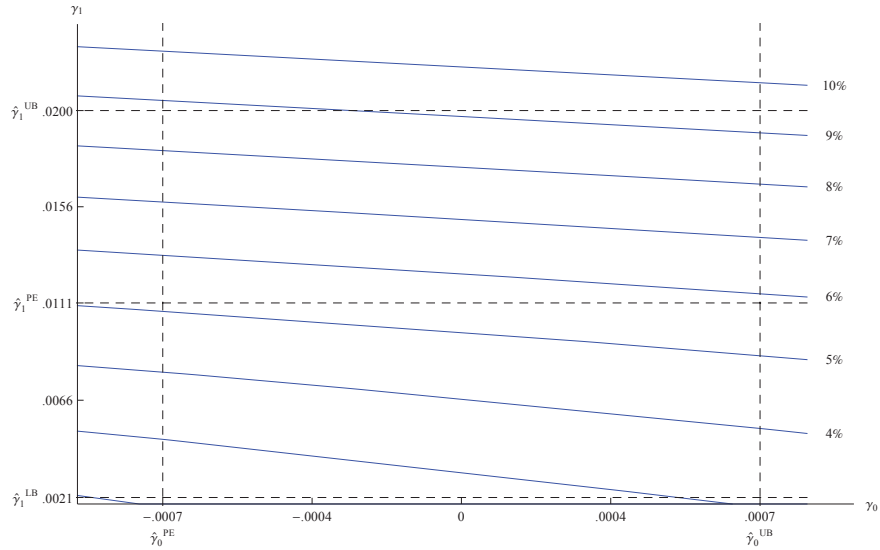


Figure 1.10: Maximum growth rates of GDP under capital controls for different calibrations of γ_0 and γ_1 . Dashed lines represented point estimates (PE) and 95% confidence interval upper (UB) and lower (LB) bounds from Section 1.2.

²⁰The welfare premium is measured in terms of the percentage that the constant level of normalized real consumption in a laissez-faire economy would need to be increased to equalize the lifetime discounted utility with that resulting from government intervention.

If we suppose that China began pursuing a mercantilist agenda through the use of capital controls following its accession to the WTO, then how well does the model fit the Chinese empirical experience over the past decade? For the benchmark calibration of the model, the values of γ_0 and γ_1 were chosen so as to set the initial growth in output of the economy under capital controls in Figure 1.11 near 9% to mimic the empirical experience of China in the 2000s. This level of growth is fairly sensitive to the chosen value of γ_1 , as shown in Figure 1.12. The model predicts a share of tradable-sector employment close to 55%, while the average share of industrial labor in China during 2000-2008 was about 24%. However, this discrepancy may simply be a matter of semantics, since the “tradable” sector includes more than just industrial production and manufacturing, as agricultural and even service industries have tradable components as well. The average share of investment in GDP in China during the same period was 44%, which is a near perfect match to the prediction of the model. However, as discussed previously, China ran a sizeable current account surplus of nearly 10% of GDP during this period, while the model does not allow for a positive current account balance during any period of the economy’s long transition of over 250 years to its steady-state equilibrium.

Finally, it should be noted that the model predicts unrealistically high levels of borrowing of over 1000% of GDP under both laissez-faire and capital controls. This is not surprising, however, given the simplifying assumptions of perfect foresight, infinitely lived consumers, and full convergence to a technological frontier that amounts

to a guaranteed long-run ten-fold increase in per-capita output. The important result is that – regardless of these simplifications – the consumer is not expected to carry a current account surplus. In the next section, I consider the sensitivity of this result to alternative calibrations of key parameters and the reasons why the mercantilist story does not seem well suited to standard dynamic macroeconomic growth models.

1.3.2 Robustness

As discussed in the previous section, the result that the economy does not amass a positive stock of foreign assets under government intervention hinges primarily upon the relative strength of two competing forces: the desire for consumption smoothing, as represented by the elasticity of intertemporal substitution ($1/\theta$), and the strength of the technological externality, as represented by the parameters in the technology equation of motion (γ_0 and γ_1). In this section, I discuss the robustness of the benchmark model's results to alternative calibrations of these parameters.

1.3.2.1 Technology Externality

The degree to which the government is enticed to suppress short term tradable consumption depends on the parameterization of the equation of motion for technology presented in (1.25). It's clear from (1.31) that lowering tradable consumption increases the share of the tradable-sector labor share, which increases tradable output, thus increasing the size of the trade balance. However, a positive net foreign

asset position could only be expected if the gains from exploiting the externality were sufficiently large to overwhelm the consumption smoothing motive, and this depends primarily upon the values of γ_0 and γ_1 .

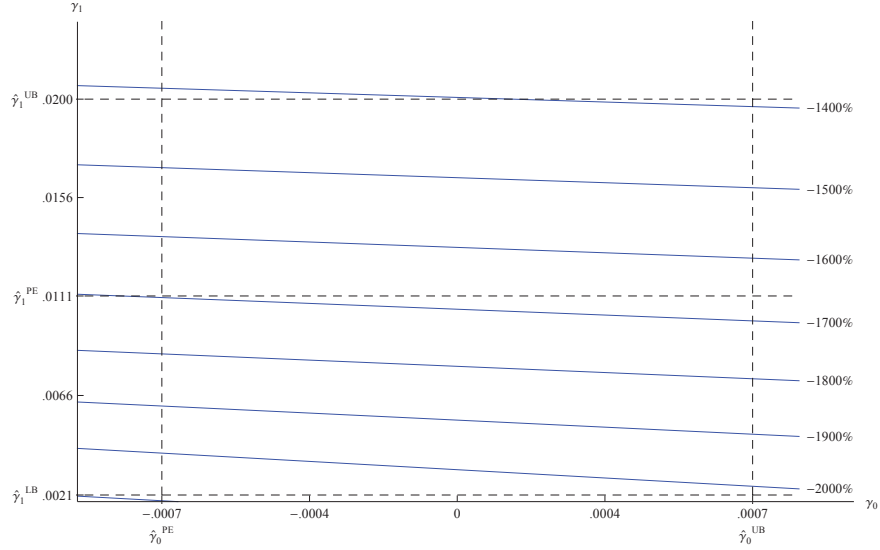


Figure 1.11: Steady-state levels of net foreign assets (NFA_t) as a percentage of GDP under capital controls for different calibrations of γ_0 and γ_1 . Dashed lines represented point estimates (PE) and 95% confidence interval upper (UB) and lower (LB) bounds from Section 1.2.

Figure 1.13 displays the long-term steady-state levels of net foreign assets under capital controls for different calibrations of the technology growth equation. If one restricts consideration to only those values that correspond to initial growth rates of around 9% under government intervention, Figure 1.13 demonstrates that the long-run impact on foreign borrowing doesn't differ substantially by parameter values. Note that even for extreme values well outside the estimated 95% confidence intervals the economy is not expected to accumulate a positive net level of external assets. Even considering empirically unjustifiable very large values of γ_1 , which maximize the

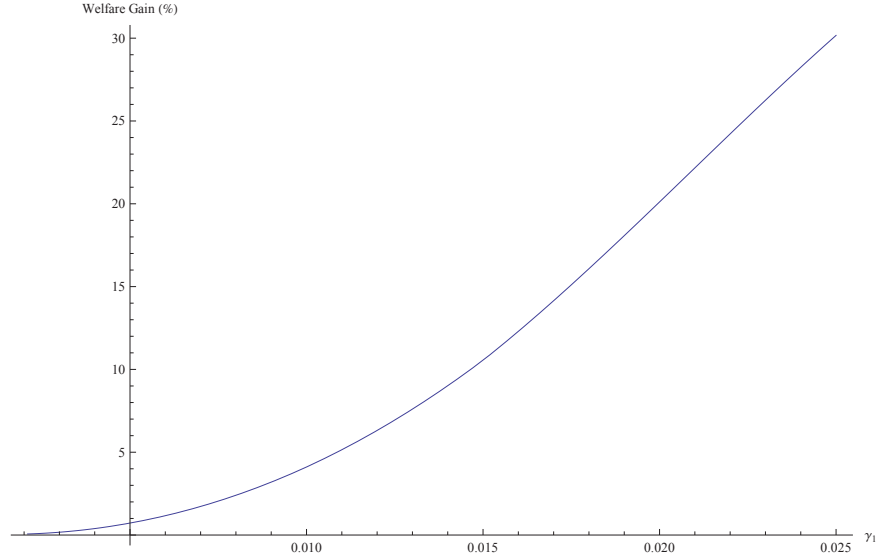


Figure 1.12: Welfare gains (in percentages of laissez-faire consumption levels) as a function of γ_1 .

externality from tradable-sector labor, the main impact is an increase in the speed of convergence to the technological frontier but no overpowering of the consumption smoothing motive that drives the economy to borrow capital from abroad. In sum, so long as the elasticity of intertemporal substitution remains sufficiently low, alternative parameterizations of the technology growth equation don't allow for positive accumulations of net foreign assets.

On the other hand, the overall welfare gains from government intervention do vary considerably with the value of γ_1 , as shown in Figure 1.14. This is because higher values of γ_1 strengthen the externality to the tradable-sector share of labor and cause faster convergence to the technological frontier, which in turn provides a higher discounted value of total output that can be allocated to consumption.

1.3.2.2 Elasticity of Intertemporal Substitution

Since the equilibrium outcome of negative net foreign assets is driven primarily by the desire for consumption smoothing, I now consider the ability of the model to match Chinese levels of external lending for alternative specifications of the elasticity of intertemporal substitution (EIS), as represented by $1/\theta$. Figure 1.15 presents the evolution of net foreign assets as a percentage of GDP when θ is decreased to .435, the temporal discount rate is correspondingly increased to .042 (so as to maintain the relationship in (1.34) when $g^* = .018$, the estimated value from Table 2.1), and the value of γ_1 is decreased to the point estimate of .0111 so as to continue matching the Chinese growth rate of 9%. The change in the EIS implies that the instantaneous utility function has less curvature, and therefore consumers are more willing to substitute consumption across time. As a result, consumers become sufficiently willing to suppress short-run consumption under government intervention to generate a positive trade balance and allow the economy to temporarily become a net lender instead of a net borrower. This value of the elasticity of intertemporal substitution was chosen so as to match the level of the Chinese current account surplus as a percentage of GDP of around 10% during the 2000s, which is demonstrated by the results in Figure 1.16.

While the positive level of net foreign assets under this alternate parameterization is a good match for the experience of China, the value of the elasticity of intertemporal substitution used is difficult to justify. For example, a meta analysis by Havranek, et al (2013) of 169 published studies that empirically estimate this elasticity using

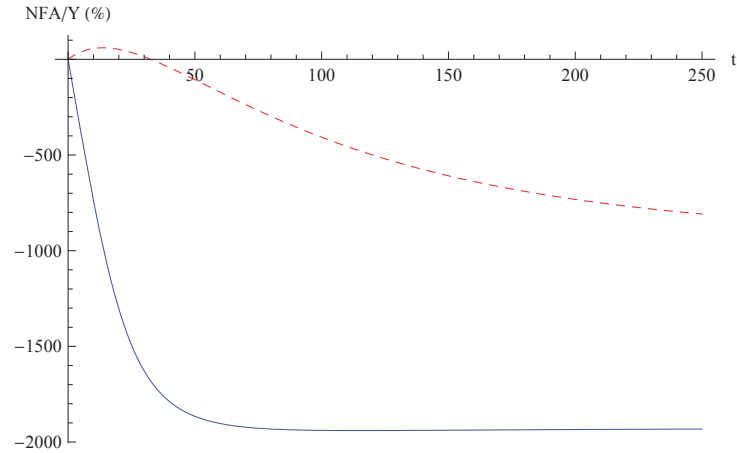


Figure 1.13: Paths of net foreign assets under laissez-faire (solid) and capital controls (dashed) as % of total output with alternate EIS.

data from a variety of countries and time periods finds a mean estimate of 0.5 (i.e. $\theta = 2$). In sum, the results suggest that it's difficult to use a dynamic macroeconomic consumption model with mercantilist policies to explain the observed levels of foreign reserves in China unless one accepts extreme parameter values that have little empirical justification.

1.3.2.3 Incomplete Technological Convergence

On a final note, the model predicts very extreme levels of borrowing that are clearly unrealistic, due to a number of simplifying assumptions including infinitely-lived consumers, no risk-premiums on debt, and complete convergence to the technological frontier/a low initial level of technology relative to the frontier. While the first two factors could be addressed by implementing additional complications in the forms of overlapping generations and interest rates endogenous to the stock of debt,

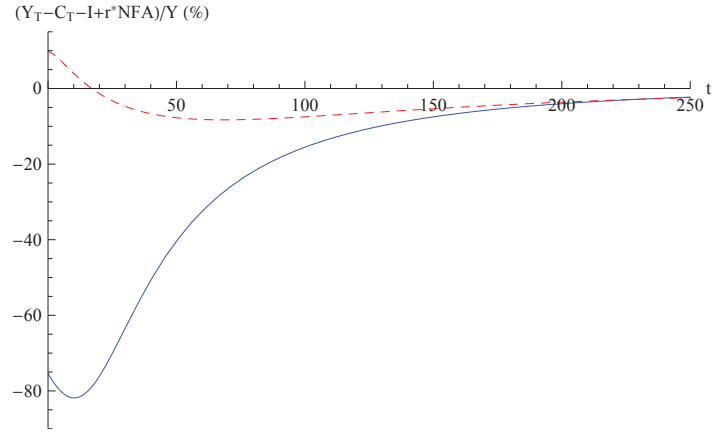


Figure 1.14: Paths of current accounts under laissez-faire (solid) and capital controls (dashed) as % of total output with alternate EIS.

the assumption of full technological convergence to the frontier can be softened in a very straightforward way by altering the value of f . Indeed, the assumption that every country in the world will eventually converge to the same long-term level of technological productivity is very strong, and it may be more realistic to assume that there will always be a “leader” who maintains a technological advantage over the rest of the world by virtue of some unique characteristics (e.g. an economic system that encourages risk, an agglomeration of human capital in a specific location, etc.).

Figures 1.17 and 1.18 present the results of the model using the parameter values in Table 2.1 in terms of foreign assets and welfare gains for a range of convergence ratios (e.g., $f = 2$ implies that the country never surpasses half of the frontier’s continually-growing level of productivity). Note that the spot estimate of $f \approx 7$ for China from Section 1.2 implies much more reasonable levels of foreign borrowing of around 100% or less of GDP. However, this level of convergence obviously implies that

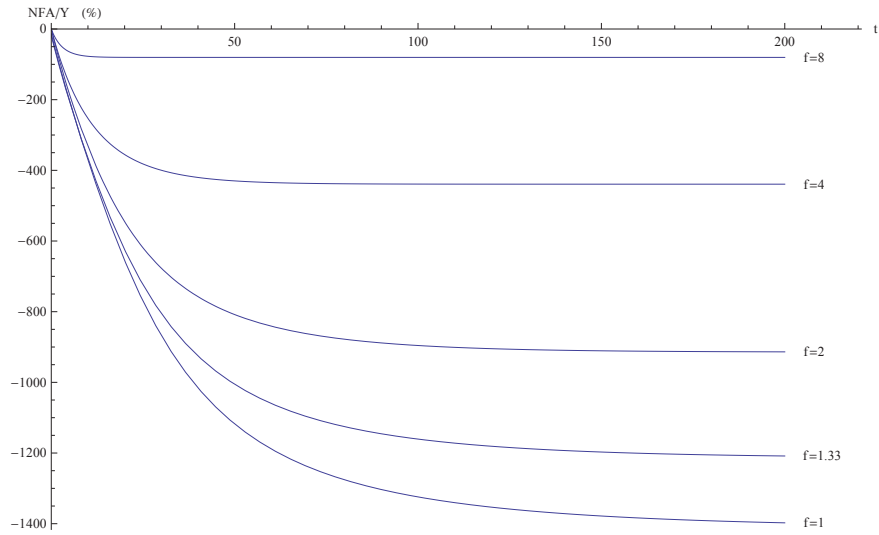


Figure 1.15: Paths of net foreign assets as a percentage of GDP for different degrees of convergence to the technological frontier.

the benefits of mercantilist policy are very short lived, such that the welfare gains would be almost negligible.

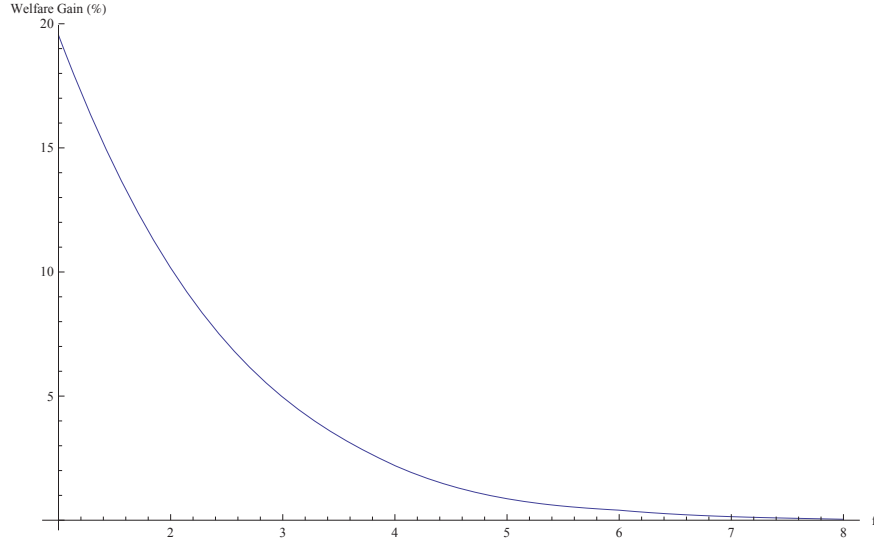


Figure 1.16: Welfare gains as a percentage of permanent laissez-faire consumption levels for different degrees of convergence to the technological frontier.

1.4 Conclusion

Overall, the model suggests that the proclivity for consumption-smoothing is the dominant characteristic of developing economies, such that the ability to exploit a productivity externality in the tradable sector does not prove sufficient to motivate a large net positive foreign asset position, such as that observed in China, under most reasonable parameterizations. However, the degree of foreign borrowing is always less under government intervention, including the imposition of capital controls, and leads to sizable welfare gains for consumers. Therefore, although the model may not predict foreign reserve holdings of the magnitudes observed in some developing countries in recent years, it may serve as part of a broader explanation for foreign asset hoarding in conjunction with other motivating factors, such as precautionary saving.

Further work could be done in this area by introducing additional market rigidities so as to allow for an analysis with interesting real exchange rate dynamics and/or introducing an overlapping generations framework so as to more realistically model saving behavior and demonstrate more plausible levels of external debt. Additionally, the model presented in this chapter could be extended to a multiple-country setting, which would also allow for the possibility of analyzing “competitive” capital accumulation among developing economies.

Chapter 2

Capital Controls, Competitive Depreciation, and the Technological Frontier

Financial flows following the recent 2007-2008 financial crises have led to renewed interest in the exercise of capital controls in emerging market economies. Furthermore, the rapid ascent of the Chinese economy over the past couple of decades while utilizing some of the world's most restrictive controls on capital flows has led to a resurgence in so-called "mercantilist" policies that promote exports as a mean of achieving economic growth. Even following many years of promoting liberalized financial accounts throughout the 1990s, the IMF has recently expressed official support for the use of capital controls in certain settings. However, much of the research on

capital controls in recent years has focused on the domestic impact of their use by a single small open economy. As stated by Ostry, et al (2010), an important consideration in the evaluation of capital control policies is the potential for multilateral spillover effects. Therefore, a key point of research continues to be the extent to which capital controls may constitute “beggar-thy-neighbor”-type policies, in which one country’s gains come at the expense of another country’s welfare. This chapter attempts to address such considerations by introducing a model of unilateral capital control use in a multi-country framework to quantify the effects on external welfare the evolution of the global economy as a whole.

Generally, the use of capital controls in emerging market economies has been promoted for two purposes. First, controls may be used to limit the disruptive effects of “hot money” inflows from carry trade. For example, Korinek and Jeanne (2010) discuss the benefits of using capital controls as a way of dealing with the negative externalities of asset price bubbles and general financial instability stemming from transitory foreign financial flows. This chapter instead focuses on a second proposed purpose of capital controls, namely the enabling of greater governmental influence over the evolution of the domestic economy. In this case, capital controls are portrayed as a means of pursuing export-promoting or “mercantilist” objectives by allocating additional resources to tradable-goods sectors of production and/or artificially undervaluing the exchange rate¹ so as to make domestically-produced goods more

¹See Jeanne (2012), for example.

attractive to foreign buyers. Often such pursuits are accompanied by an implicit assumption about the relative superiority of the tradable-goods sector in contributing to a country's overall economic growth. Many recent studies, including Korinek and Serven (2010), Michaud and Rothert (2014), and Benigno and Fornaro (2014), have demonstrated welfare gains resulting from the unilateral use of capital controls for such purposes. However, all of these examples have done so within the context of a single small open economy.

Often, the discussion of capital controls as a means of pursuing a mercantilist agenda is used to try to motivate the massive accumulation of foreign assets by China over recent years. However, the studies above have had little success in doing so, particularly because a country with the world's largest population and second largest nominal GDP in no way fits the designation of "small." More realistically, policies that induce large capital inflows or outflows should affect a country's ability to borrow or lend at a given rate of interest. In other words, if this line of literature hopes to understand China, it must consider its position as a *large* economy with corresponding impacts on other countries in a global economic setting. Obviously, the implementation of government policies that affect the determination of a country's current account, regardless of intended purpose, must have effects on its trading partners as well. This chapter attempts to quantify these international effects by introducing a model with multiple countries with differing motivations.

In this chapter, I assume the existence of a "developed" economy that operates at

a “global technological frontier”, such that it is the most productive economy in the world. The frontier-defining level of technology continually progresses over time due to innovations unique to the developed country’s economy. The developed country trades internationally with other countries that converge or “catch-up” over time to its frontier-defining level of productivity at a rate that is endogenous to the domestic allocation of labor. That is, the greater the share of “human capital” devoted to the production of tradable goods, the more quickly a “developing” country can adopt the newest technologies and best practices by virtue of exposure to the advanced international market. Furthermore, I assume this degree of technological adaptation has positive spillovers to the rest of the economy that are not recognized by individual firms.

The government can therefore play a welfare-optimizing role through implementation of appropriate policy to achieve a better technological-growth inducing allocation of labor in the economy. Since individual firms in the tradable sector don’t internalize the impact of their employment decisions on aggregate productivity, they “under-hire” relative to the share of employment a social planner would assign to the production of tradable goods. Government action could correct this inefficiency in a *first-best* manner by introducing appropriate price-based policy options, such as production and/or wage subsidies in the tradable-goods sector, consumption taxes, and/or a combination of import tariffs and export subsidies. An ad valorem tax on tradable goods, for example, would induce a lower level of tradable consumption,

and by extension a lower level of nontradable consumption, conditional on their being complementary. Since all nontradable output must be consumed domestically by definition, a concurrent fall in domestic demand for nontradable goods will induce a reduction in employment in the nontradable sector, which will shift to the production of tradable goods, thereby hastening the pace of technological adoption and simultaneously increasing the country's trade balance, potentially financing a current account surplus.

However, keeping in line with related literature, I assume that each of these policy options are infeasible for one or more of the following reasons: First, government actors may suffer from targeting problems, inasmuch that they are unable to correctly identify the specific firms and industries that would most greatly contribute to productivity growth. Second, and related to the first point, there may exist overly dear rent-seeking costs or political frictions associated with lobbying efforts by firms and/or labor unions interested in receiving such subsidies or pecuniary protections. Third, and most importantly, any government policy may potentially conflict with international obligations the country faces as a member of multilateral organizations, such as the World Trade Organization and International Monetary Fund. Most of the price-based interventions mentioned above could possibly violate the WTO's restrictions on international dumping or be construed as giving domestic exporting industries an unfair advantage in the global market. Because of the potential for censure and/or authorization of countervailing measures by the WTO dispute settlement

body, such economic guidelines carry weight are generally viewed as being legitimately restrictive. However, since the WTO's regulation of international trade only applies to one side of a country's balance of payments, many of the same policy objectives can be achieved through the use of appropriate controls on the international flow of assets. While the IMF acts as overseer of global financial capital movements and its membership articles discourage the use of capital controls,² it doesn't have the same "teeth" in terms of active enforcement of a strict set of regulations.

As such, the government can play a welfare-improving role in the economy by using transfer payments and/or domestic bonds to alter the flow of income to domestic households, while instituting strict capital controls as a *second-best* policy alternative in order to prevent households from engaging in offsetting borrowing/lending with foreigners. By properly doing so, the government can still achieve its objective of directing more labor into the production of tradable goods, thereby increasing the rate of technological catch-up and increasing the country's present-discounted level of total output. In turn, the rates of interest applicable to international capital flows are endogenously determined in the global market by the actions of each economy. While it's obvious that the use of capital controls to correct for productivity externalities at the household/firm level will result in welfare improvements for an individual developing economy, it is less clear what the impacts are on a country already at

²While the IMF's official stance on the use of capital controls has been slowly evolving in the wake of the 2008 global financial crisis to be more accepting of their use, such acceptance is still conditional on asset flow restrictions being used as a policy of last resort and only *temporarily*, in contrast to their long-term use in countries such as China and India for structural and developmental purposes.

the technological frontier and on other similarly developing economies that may or may not also be employing mercantilist policies. In other words, should the United States be threatened by a growing, mercantilist China? Should Brazil feel compelled to employ similar policies or will it be left behind by a mercantilist Chinese economy?

To address these questions, I consider three scenarios: 1) a two-country setting in which a “frontier” country exists alongside a single other developing economy that employs capital controls as a means to quicken its rate of technological “catch-up”, 2) a three-country setting in which two developing economies both simultaneously attempt to use capital controls to speed up their rates of convergence, and 3) a three-country setting in which the frontier country and a developing economy operate under laissez-faire regimes while a second developing economy singularly employs mercantilist policy. The key question of interest is whether any countries in these scenarios experience welfare “losses”, relative to laissez-faire settings, as a result of another country’s use of capital controls. I find that the frontier country is likely to be worse-off as a result of mercantilist policies on the part of developing economies (depending on the model parameterization and how many countries have instituted capital controls). Furthermore, I show that a second developing economy not making use of government policy in the presence of a “competing” developing economy can be made worse-off. In other words, China’s use of capital controls may spur other developing countries, such as Brazil, to follow suit, legitimizing the multilateral concerns of Ostry, et al (2010). Finally, the model also displays a much easier ability

to match the asset accumulation behavior of China relative to previous studies as a result of interest rate dynamics.

I proceed by introducing the theoretical model in Section 2.1, outlining the chosen parameterization of the model in Section 2.2, explaining the results in Sections 2.3 and 2.4, and concluding with some final thoughts in Section 2.5.

2.1 Model

For each country, indexed by $i \in \{1, 2, 3\}$, the economy allows for a representative consumer who maximizes lifetime welfare:

$$W_i = \int_0^\infty u(C_{it})e^{-\rho t} dt \quad (2.1)$$

where $u(C_{it}) = C_{it}^{1-\theta}/(1-\theta)$ is a CRRA felicity function (such that $1/\theta$ represents the elasticity of intertemporal substitution) and C_t is a consumption index of tradable (T) and nontradable (N) goods, defined by:

$$C_{it} = C_{Tit}^\phi C_{Nit}^{1-\phi} \quad (2.2)$$

where $0 < \phi < 1$ and tradable goods serve as the numeraire for the economy.

Households in each economy earn income from providing labor inelastically in return for wages W_{it} and earn dividends from the profits Π_{it} of firms in the economy,

which they can spend on foreign assets B_{it} and consumption, such that the economy's dynamic budget constraint can be expressed in aggregate as:

$$\dot{B}_{it} = r_t B_{it} + W_{it} + \Pi_{it} - \frac{1}{q_{it}} C_{it} \quad (2.3)$$

where q_{it} represents the relative price of tradable goods in terms of the consumption index (and serves as the economy's real exchange rate), and r_t is the international rate of interest on foreign assets (which are assumed to be homogeneous across countries in terms of risk and liquidity).

Firms operate competitively in the economy's two sectors, such that aggregate output can be expressed as:

$$Y_{Nit} = A_{it} L_{Nit}^{\alpha_i} \quad (2.4)$$

$$Y_{Tit} = A_{it} L_{Tit}^{\alpha_i} \quad (2.5)$$

where $0 < \alpha_i \leq 1$, reflecting diminishing marginal returns to labor, which is the only choice input into production and is augmented by the level of productivity/technology A_{it} in the economy. The aggregate amount of labor in each economy is normalized to unity, such that $L_{Tit} + L_{Nit} = 1$.³ Thus, firms profits' (denominated in tradable

³In this sense, the economies are all "large" in terms of relative population sizes.

goods) are defined in aggregate by

$$p_T \Pi_{it} = p_T \Pi_{Tit} + p_{Nit} \Pi_{Nit} \quad (2.6)$$

$$\Pi_{it} = (Y_{Tit} - W_{it}L_{Tit}) + (p_{it}Y_{Nit} - W_{it}L_{Nit}) \quad (2.7)$$

where p_{it} represents the relative price of nontradables to tradables.

In all settings of the model, I assume that Country 1 has the highest global level of technology, which grows at the constant rate of g as follows:

$$A_{1t} = A_{10}e^{gt}. \quad (2.8)$$

Being at the world “technological frontier” further implies that Country 1 is special in the sense that its advancements are by virtue of pure innovation and stretching the boundaries of existing productive knowledge. This may be because the economy has a unique set of institutional characteristics that enable it to develop and attract human capital relatively more successfully than other countries and thereby take advantage of special economies of agglomeration in terms of research and development.

By comparison, other countries in the world exhibit levels of technology that also grow at the rate g plus an additional growth premium, which mainly reflects the “advantage” of these countries’ relative backwardness in allowing them to imitate and implement already established technologies rather than purely innovating new ideas and techniques. Over time, these countries’ levels of technology catch-up to the global

“frontier” at a rate that is determined as a function of the share of labor employed in the production of tradable goods. More specifically, I assume that the levels of technology in these “developing” economies progresses according to the following:

$$\frac{\dot{A}_{it}}{A_{it}} = g + \left(\gamma_0 + \gamma_1 L_{Tit} \right) \left(\frac{A_{1t}}{A_{it}} - 1 \right). \quad (2.9)$$

where $\gamma_1 > 0$. This is the same assumption used in Chapter 1, based on a model of technological diffusion first used by Nelson and Phelps (1966), and can be thought of as a “learning-by-doing” externality to productivity, as individual firms do not internalize the effects of their employment decisions on the aggregate level of technology in the economy. Intuitively, the assumption is that having a larger share of the domestic workforce more directly exposed to the advanced competition in the international marketplace facilitates faster implementation of best-practices and more efficient production methodologies that also have spillover effects into the domestic nontradable sector.

To simplify the exposition, from here on lower-case letters will denote variables that have been normalized by the frontier level of technology in Country 1, e.g. $c_{it} = C_{it}/A_{1t}$.

2.1.1 Equilibrium Conditions

Labor is assumed to be mobile between sectors domestically, but not internationally, such that wages are equalized across sectors. Firms maximize profits by hiring labor to equalize wages and the marginal product of labor, yielding the following first-order conditions

$$w_{it} = \alpha_i a_{it} L_{Tit}^{\alpha_i - 1} \quad (2.10)$$

$$w_{it} = p_{it} \alpha_i a_{it} L_{Nit}^{\alpha_i - 1} \quad (2.11)$$

Consumers maximize their consumption index by consuming tradable and nontradables so as to equalize the ratio of marginal utilities to their relative prices, yielding the following first-order condition

$$p_{it} = \frac{1 - \phi}{\phi} \frac{c_{Tit}}{c_{Nit}} \quad (2.12)$$

Furthermore, all nontradables must be consumed domestically, by definition, such that

$$c_{Nit} = a_{it} L_{Nit}^{\alpha_i} \quad (2.13)$$

Therefore, using the aggregate labor constraint $L_{Tit} + L_{Nit} = 1$, these conditions collectively define the following intratemporal first-order conditions that each economy

must satisfy at every point in time:

$$\alpha_i a_{it} L_{Tit}^{\alpha_i-1} = w_{it} \quad (2.14)$$

$$p_{it} \alpha_i a_{it} (1 - L_{Tit})^{\alpha_i-1} = w_{it} \quad (2.15)$$

$$\frac{1-\phi}{\phi} \frac{c_{Tit}}{a_{it}} (1 - L_{Tit})^{-\alpha_i} = p_{it} \quad (2.16)$$

Because in equilibrium a chosen level of tradable consumption automatically implies a corresponding utility-maximizing level of nontradable consumption (and hence aggregate real consumption), we can think of each consumer as choosing the optimal path of c_{Tit} over time. Thus, since c_{Tit} is a control variable and a_{it} is a state variable, this system of three equations establishes the values of the three endogenous variables $\{p_{it}, w_{it}, L_{Tit}\}$. Note that this nonlinear system of equations does not allow for explicit reduced-form expressions for p_t , w_t , and L_{Tt} individually; however, by combining (2.10)-(2.13) and taking the derivative with respect to c_{Tit} , we find that

$$\frac{\partial L_{Tit}}{\partial c_{Tit}} = - \frac{(1-\phi) L_{Tit}^{2-\alpha_i}}{\phi a_{it} ((1-\alpha_i) + \alpha_i L_{Tit})} < 0. \quad (2.17)$$

Therefore, c_{Tt} and L_{Tt} have an inverse relationship, meaning that an economy can induce a shift of employment into the tradable sector – thereby boosting its speed of technological growth – by *reducing* its current level of consumption. In other words, the act of repressing tradable consumption simultaneously boosts the production of tradable output, thereby increasing the trade balance and financing a higher net

foreign asset position. If the productivity externality is sufficiently strong, this relationship could provide the motivation behind running trade surpluses and amassing net foreign wealth in order to support faster economic growth.

In a corollary to the intratemporal maximization condition in (2.12), the real exchange rate at any point in time can be expressed as

$$q_{it} = \frac{\partial c_{it}}{\partial c_{Tit}} = \phi \left(\frac{c_{Tit}}{c_{Nit}} \right)^{\phi-1} \quad (2.18)$$

Finally, world equilibrium stipulates that total exports must equal total imports at all points in time, such that the following must hold:

$$\sum^i (y_{Tit} - c_{Tit}) = 0 \quad (2.19)$$

In order for this relationship to always hold true, the endogenous rate of interest on foreign assets in the world economy adjusts to encourage or discourage the intertemporal displacement of consumption that motivates trade imbalances.

2.1.2 Consumer's Problem Under Laissez-faire

The representative consumer's problem in each country under laissez-faire is:

$$\max_{c_{it}} \int_0^\infty \hat{u}(c_{it}) e^{-(\rho - g(1-\theta))t} dt \quad (2.20)$$

$$s.t. \quad \dot{b}_{it} = (r_t - g)b_{it} + w_{it} + \pi_{it} - \frac{1}{q_{it}}c_{it} \quad (2.21)$$

where r_t , w_{it} , π_{it} , and q_{it} are taken as given by the consumer, and $\hat{u}(\bullet)$ represents the technology-normalized version of the felicity function in (2.1). Additionally, the consumer is further restrained by a standard “no-Ponzi” borrowing condition, i.e.

$$\lim_{t \rightarrow \infty} b_{it} e^{-\int_0^t r_s ds} \geq 0. \quad (2.22)$$

Optimal control theory suggests the following first-order maximization condition:

$$\frac{\dot{c}_{it}}{c_{it}} = \frac{r_t - \rho}{\theta} - g + \frac{1}{\theta} \frac{\dot{q}_{it}}{q_{it}} \quad (2.23)$$

such that the consumer maximizes welfare by smoothing consumption over time with respect to the changing rate of interest and the exchange rate.

2.1.3 Social Planner's Problem and Government Intervention

For developing countries, a social planner acting to correct the extant productivity externality faces the following problem:

$$\max_{c_{it}} \int_0^\infty \hat{u}(c_{it}) e^{-(\rho-g(1-\theta))t} dt \quad (2.24)$$

$$s.t. \quad \dot{b}_{it} = (r_t - g)b_{it} + w_{it} + \pi_{it} - \frac{1}{q_{it}}c_{it} \quad (2.25)$$

$$\dot{a}_{it} = (\gamma_0 + \gamma_1 L_{Tit})(1 - a_{it}) \quad (2.26)$$

such that an omniscient planner explicitly takes the externality to productivity into account. The planner is large enough to recognize the impact of its consumption decision on the domestic prices w_{it} , π_{it} , and q_{it} , although I continue to assume for simplicity that the international rate of interest is taken as given from the point of view of each individual country in a form of limited rationality (perhaps because of insufficient financial infrastructure to fully and accurately account for the country's individual effect on the world asset market), although the countries do have rational expectations in regards to the world interest rate's future path.

The social planner's solution differs from the previous section because it recognizes the benefit of higher tradable-sector employment, namely that technology improves at a faster rate in both the tradable and nontradable sectors, thus increasing the

country's total lifetime output. As such, the social planner explicitly uses the relationship in (2.17) to boost the short-run levels of employment in the tradable sector by *repressing* the initial levels of tradable consumption relative to the representative household under laissez-faire. Then, as the country's output grows at an accelerated rate, the country can enjoy a faster rate of consumption growth and ultimately a higher long-run level of consumption relative to the laissez-faire setting, thus boosting the country's welfare.

As discussed in the introduction, a government actor in a developing country can attempt to mimic the social planner's optimal solution through the use of appropriate intervening policy. In a first-best scenario, the government could directly target the share of tradable-sector employment by using price-based policies such as wage subsidies, consumption taxes, and/or a mix of import tariffs and export subsidies to increase the incentives associated with employment in the tradable sector. However, I assume that the government's portfolio of policy options is restricted by its membership in the WTO, and any such price-based interventions would be considered to be providing an illegal competitive advantage to domestic industries relative to the global marketplace.

Instead, I suppose that the government turns to its second-best policy alternative and intervenes in the decentralized, laissez-faire economy of a country by instituting strict capital controls on international borrowing and lending activities by domestic households, such that $b_{it} = 0$ for all $t \geq 0$. Furthermore, suppose that the govern-

ment interacts with private households via lump-sum transfer payments (denoted in technology-normalized terms by z_{it}) and the issue of domestic bonds (denoted by b_{it}^D), which differ from other assets in that they are only available to domestic actors and pay interest at the domestic rate of r_{it}^D , such that we can express that economy's dynamic budget constraint as

$$\dot{b}_{it}^D = (r_{it}^D - g)b_{it}^D + w_{it} + \pi_{it} - \frac{1}{q_{it}}c_{it} + z_{it}. \quad (2.27)$$

Meanwhile, the government may continue to engage in international transactions to accumulate its own stock of foreign assets (denoted by B_{it}^G to differentiate from total net foreign assets held by the economy under laissez-faire) subject to the following dynamic budget constraint (in technology-normalized terms):

$$\dot{b}_{it}^D + (r_t - g)b_{it}^G = \dot{b}_{it}^G + (r_{it}^D - g)b_{it}^D + z_{it}. \quad (2.28)$$

Combining the previous two equations yields the following consolidated dynamic budget constraint for the economy as a whole:

$$\dot{b}_{it}^G = (r_t - g)b_{it}^G + w_{it} + \pi_{it} - \frac{1}{q_{it}}c_{it}. \quad (2.29)$$

which is identical to the laissez-faire constraint in (2.3), except that national net foreign assets are now uniquely controlled by the government. Next, notice that we

can also express aggregate profits in (2.7) as

$$\pi_{it} = y_{Tit} + p_{it}y_{Nit} - w_{it} \quad (2.30)$$

Then, using this expression and the intratemporal equilibrium conditions for p_{it} and q_{it} from (2.12) and (2.18), respectively, the consolidated budget constraint can also be expressed as

$$\dot{b}_{it}^G - (r_t - g)b_{it}^G = y_{Tit} - c_{Tit}. \quad (2.31)$$

Thus, we can see that the left-hand side of this expression is at the sole discretion of the government and, by virtue of the relationship in (2.17), the right-hand side can be considered a function solely of c_{Tit} . Furthermore, note that the expressions in (2.2), (2.12), and (2.13) imply that the aggregate real consumption index can also be expressed in equilibrium as a function solely of tradable consumption c_{Tit} . Therefore, the government can effectively choose the path of aggregate real consumption in the economy through the appropriate use of bond issuance and/or transfer payments along with capital controls. By extension, if the government has the ability to choose any feasible path of real consumption, then it has the power to perfectly implement the social planner's welfare-maximizing consumption path that solves the problem presented at the beginning of this section.

2.2 Parameterization

The parameter values used in the numerical solution to the model are shown in Table 2.1. The growth rate of the international technology frontier comes from Chapter 1, wherein estimates of total factor productivity from over 100 countries are used to define the frontier as the most technologically advanced economy in every period from 1960-2009 (which corresponds to the United States in nearly every year). The observed growth rate of the technological frontier over that entire time horizon is about 1.8% in annualized terms.

Chosen values of .02 for the intertemporal discount rate ρ and 1.5 for the coefficient of relative risk aversion are from within standard ranges.⁴ The tradables income share ϕ of 0.3 comes from Mendoza (2003) and falls within generally accepted ranges. In the benchmark model, the labor elasticity of output is set at approximately 2/3 for every country.

I assume that the initial level of net foreign assets for each country has been normalized to zero. Furthermore, I assume that the least technologically developed country in all settings begins has an initial normalized level of technology of 1, relative the initial frontier-country level of 10, following the estimation of relative productivity levels between China and the United States in 2000 (also taken from Chapter 1). In the three-country setting, I assume that second developing economy is slightly more

⁴Note that this implies an elasticity of intertemporal substitution of $1/\theta \approx 0.67$, which is well within country-level empirically estimated ranges. See Havnarek, et al (2013) for an overview of this estimation literature.

advanced, with an initial technology level of 2. The parameter values defining the strength of the tradable sector productivity externality in (2.9) (specifically, $\gamma_0 = 0$ and $\gamma_1 = 0.02$) are also both taken from the benchmark model estimates in Chapter 1.

g	.018	Frontier Tech. Growth Rate
ρ	.02	Standard Range
θ	1.5	Standard Range
ϕ	0.3	Mendoza (1995)
α_i	2/3	Standard
B_{i0}	0	Assumed
A_{10}	10	U.S. relative to China in 2000
A_{20}	1	U.S. relative to China in 2000
A_{30}	2	Assumed
γ_0	0	Chapter 1
γ_1	.02	Chapter 1

Table 2.1: Chosen parameter values.

2.3 Two Countries

2.3.1 Laissez-faire

First, I consider a two-country world comprising one “developed” country ($i = 1$), whose level of technology defines the global frontier, and one “developing” economy

($i = 2$), which starts out with a much lower level of productivity.

In order to better explain the intuition behind the results, I consider for a moment the conditions of the model in the extreme case that $\alpha_i = 1$ for $i = 1, 2$, which fully allows for closed-form expressions of the intratemporal equilibrium pricing conditions (unlike the more general expressions in (2.14) - (2.16)) while still preserving the same general relationships between the key variables.⁵ Thus, the equilibrium wage conditions in (2.10) and (2.11) become

$$a_{it} = w_{it} \tag{2.32}$$

$$p_{it}a_{it} = w_{it}, \tag{2.33}$$

which together imply

$$p_{it} = 1. \tag{2.34}$$

Thus, along with (2.12), we can express nontradable consumption as

$$c_{Nit} = \frac{1 - \phi}{\phi} c_{Tit}. \tag{2.35}$$

⁵The assumption that $\alpha = 1$ sacrifices the desired characteristic of diminishing marginal returns to labor in production and requires additional constraints to ensure positive values of consumption and labor, but can be numerically shown to exhibit the same effects of consumption on the endogenous interest rate as the model wherein $0 < \alpha < 1$.

Furthermore, using (2.16) we can express the share of labor in the tradable sector as

$$L_{Tit} = 1 - \frac{1 - \phi}{\phi} \frac{c_{Tit}}{a_{it}}. \quad (2.36)$$

The Euler equation defining optimal consumption paths from (2.23) can thus be written as

$$\dot{c}_{Tit} = \left(\frac{r_t - \rho}{\theta} - g \right) c_{Tit}. \quad (2.37)$$

Finally, the equilibrium expression for the international rate of interest r_t can be found by combining the production function for tradable goods in (2.5) with the global trade equilibrium from (2.19) and differentiating with respect to time, then using the conditions above – along with the equation of motion for technology from (2.9) – as follows:

$$0 = (y_{T1t} - c_{T1t}) + (y_{T2t} - c_{T2t}) \quad (2.38)$$

$$0 = L_{T1t} - c_{T1t} + a_{2t}L_{T2t} - c_{T2t} \quad (2.39)$$

$$0 = \left(1 - \frac{1 - \phi}{\phi} \frac{c_{T1t}}{1} \right) - c_{T1t} + a_{2t} \left(1 - \frac{1 - \phi}{\phi} \frac{c_{T2t}}{a_{2t}} \right) - c_{T2t} \quad (2.40)$$

$$0 = \dot{a}_{2t} - \frac{1}{\phi} \dot{c}_{T2t} - \frac{1}{\phi} \dot{c}_{T1t} \quad (2.41)$$

$$0 = \dot{a}_{2t} - \frac{1}{\phi} \left(\frac{r_t - \rho}{\theta} - g \right) c_{T2t} - \frac{1}{\phi} \left(\frac{r_t - \rho}{\theta} - g \right) c_{T1t} \quad (2.42)$$

$$r_t = \left(\frac{\dot{a}_{2t}}{c_{T2t} + c_{T1t}} + \frac{g}{\phi} \right) \theta \phi + \rho \quad (2.43)$$

$$r_t = \frac{\theta \phi \left(\gamma_0 + \gamma_1 \left(1 - \frac{1 - \phi}{\phi} \frac{c_{T2t}}{a_{2t}} \right) \right) (1 - a_{2t})}{c_{T2t} + c_{T1t}} + \theta g + \rho \quad (2.44)$$

These equations reveal two important features of the model: First, all else equal, the interest rate is a *decreasing* function of tradable consumption in either country.⁶ In other words, a higher interest rate induces a higher level of national savings, which coincides with a lower level of consumption. Second, as the developing country's level of technology approaches the frontier its growth rate falls regardless of consumption levels, therefore implying that the interest rate will ultimately converge to a long-run steady-state level of $\theta g + \rho$ (this is also clearly true for the model wherein $0 < \alpha < 1$, as seen by setting $\dot{c}_{it} = 0$ and $\dot{q}_{it} = 0$ in (2.23)).

A helpful starting point for thinking about the evolution of the economy is to consider the case in which technology in Country 2 also grows at Country 1's fixed rate of growth, g . In such a setting, $\dot{a}_{2t} = 0$ meaning that the equilibrium condition in (2.43) implies r_t is constant over time. By extension, (2.37) implies that consumption is constant. Intuitively, both countries' economies are growing over time, fueling a desire to borrow against future income to smooth out their consumption paths. However, since their growth rates are equal and any current account imbalance in one country must be met by an opposite imbalance in the other country, their equal desires to borrow (or equivalently not to lend) cancel each other out and they behave as if in autarky. By contrast, in a model where Country 2 exhibits a faster rate of growth due to its ability to "catch-up" according to the technology evolution function in (2.9), it has a relatively stronger desire to borrow because the faster rate of technological

⁶Assuming that $c_{Tit} \geq 0$, $L_{Tit} \geq 0$, and γ_0 is not very negative (Note that $\gamma_0 \leq 0$ would imply a degree of unconditional "falling behind" in terms of technology on the part of developing countries).

adaptation contributes to a higher level of future output to borrow against.

Therefore, in a laissez-faire setting without government actors or capital flow restrictions, the evolution of the world system is characterized by the developing economy's anticipation of tremendous growth in output over the coming years and its attempt to smooth its consumption profile by borrowing massive amounts of tradable income from the developed economy. Therefore, the net foreign asset positions of the two countries tell a story of two extremes: perpetual borrowing and debt servicing on the part of the developing economy and the continual inflow of assets and interest income on the part of the developed economy.

In the developing economy, the share of labor in the tradable sector is initially low as the economy looks to import most of its tradable consumption in the short-run in order to shift its consumption intertemporally toward the present. Eventually, however, the mounting interest obligations on its debt require the economy to shift labor into the production of tradable goods, causing a great acceleration in the rate of technological catch-up, until both economies finally settle into a long-run steady-state dynamic equilibrium.

2.3.2 Capital Controls

If the government in the developing economy implements capital controls, the evolution of the world system looks substantially different. The government, in recognizing the externality to tradable production, represses short-run consumption (relative

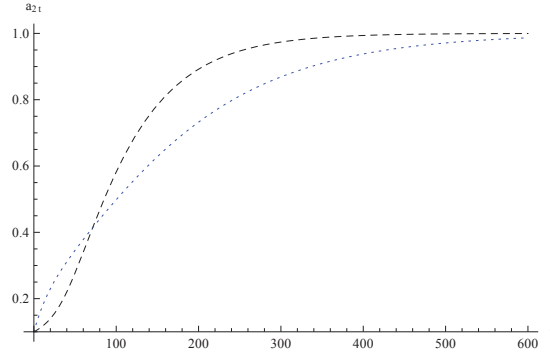


Figure 2.1: Technology paths. Laissez-faire - Black dashed. Capital controls - Blue dotted.

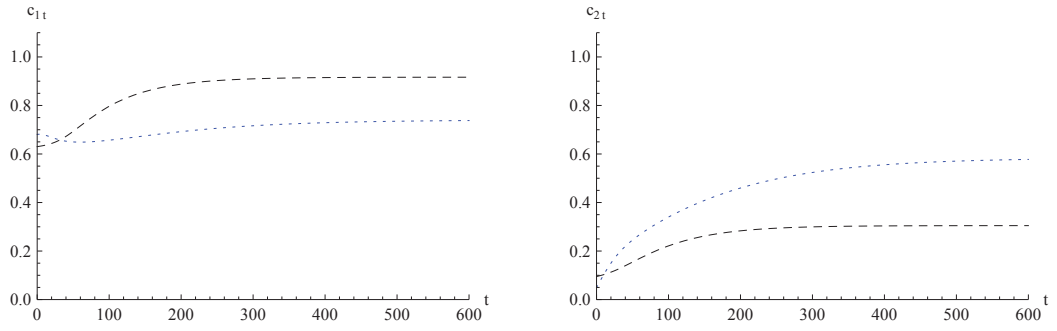


Figure 2.2: Consumption paths. Laissez-faire - Black dashed. Capital controls - Blue dotted.

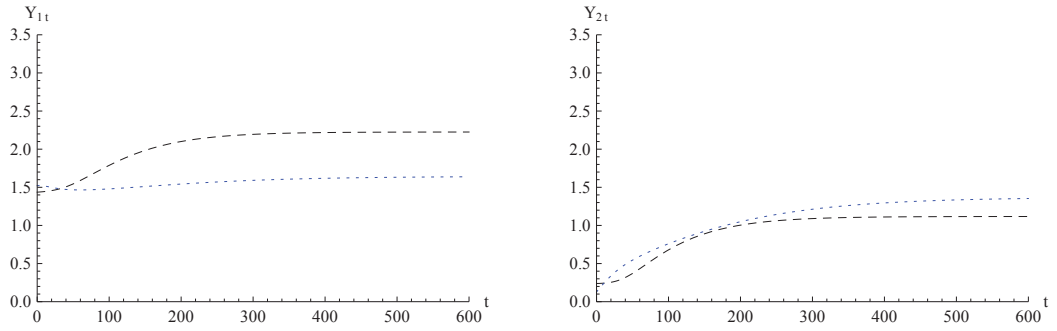


Figure 2.3: Output paths ($Y_{it} = Y_{Tit} + p_{it}Y_{Nit}$). Laissez-faire - Black dashed. Capital controls - Blue dotted.

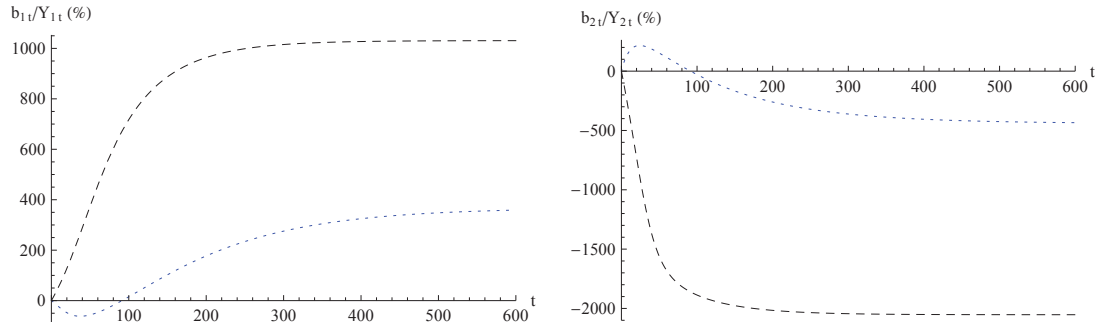


Figure 2.4: Net foreign asset paths (%). Laissez-faire - Black dashed. Capital controls - Blue dotted.

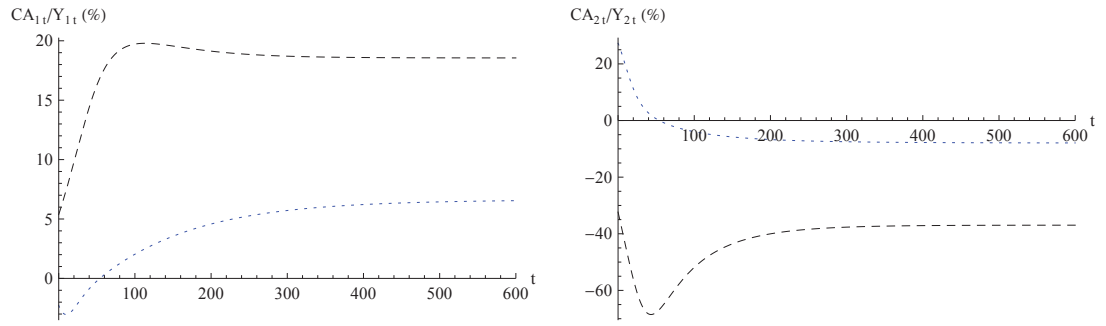


Figure 2.5: Current account paths (%). Laissez-faire - Black dashed. Capital controls - Blue dotted.

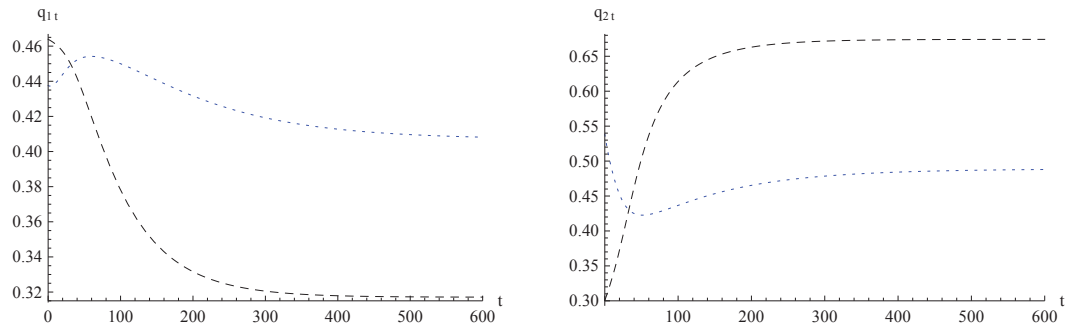


Figure 2.6: Exchange rate paths. Laissez-faire - Black dashed. Capital controls - Blue dotted.

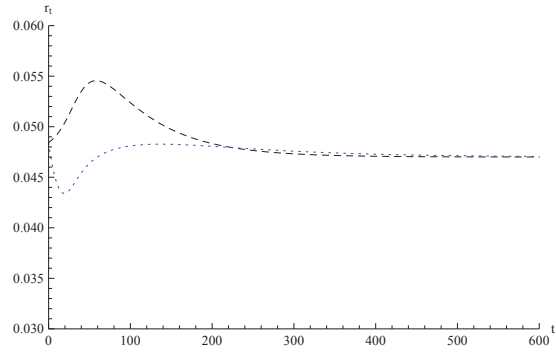


Figure 2.7: Interest rate paths. Laissez-faire - Black dashed. Capital controls - Blue dotted.

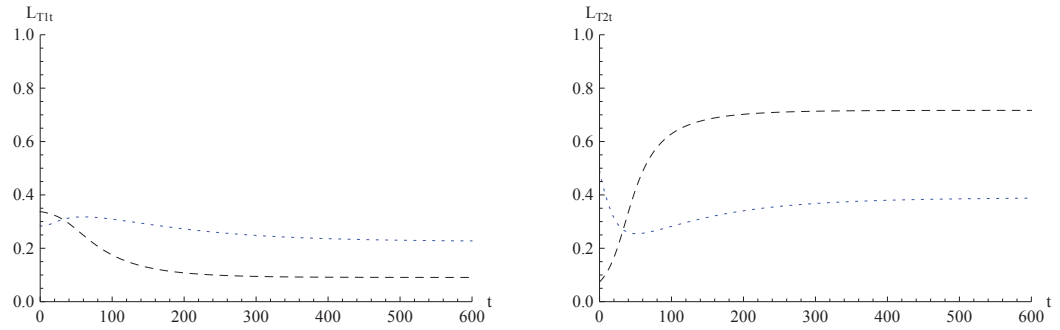


Figure 2.8: Labor share paths. Laissez-faire - Black dashed. Capital controls - Blue dotted.

to the laissez-faire case) thereby leading to a relatively higher share of employment in the tradable-goods sector. This higher level of tradable employment results in faster productivity growth, which fuels a relatively faster rate of output growth. Because the reduced level of consumption correlates with an increased level of output, the developing economy in this setting – instead of borrowing – initially runs a trade surplus with the developed economy. This results in a sizable positive net foreign asset position in the developing economy concomitant with capital inflows to the developed economy, reminiscent of the recent current account imbalances between the United States and China. Essentially, by instituting capital controls and redirecting the flow of domestic income, the government in the developing economy “artificially” changes the balance between the two countries’ simultaneous desires to borrow against their future income streams, such that Country 1 is now willing to provide the loans that Country 2 desires on enticing terms.

In order to fully understand the impact of the developing country’s actions on the evolution of the developed economy, one needs to consider the relationship between consumption decisions and the real exchange rate and the international rate of interest, as expressed by the Euler equation in (2.23). From the developed economy’s point of view, the cost of borrowing from abroad for one additional unit of the tradable good today is approximately $(1 + r_t)$ tradable goods one year in the future, or $q_{1t}(1 + r_t)$ units of the real consumption good (which is what consumers actually derive utility from and ultimately care about the most). Since Country 2 represses its short-run

consumption, the world interest rate under capital controls initially *rises* very slightly relative to the laissez-faire interest rate (albeit briefly), making the cost of borrowing *higher*, ceteris paribus. However, note that a fall in tradable consumption implies a concomitant fall in nontradable consumption, thereby implying by (2.18) that any decrease (increase) in consumption coincides with an appreciation (depreciation) of the economy's real exchange rate. Thus, relative to the laissez-faire setting, the developing economy's implementation of capital controls and short-run repression of consumption lead to an initial depreciation of its real exchange rate, and likewise an initial appreciation of the developed economy's real exchange rate (fall in q_{10}), thereby *lowering* its perceived cost of borrowing. In each country, the change in the exchange rate is a reflection of the shifting composition of the labor market (i.e. a higher share of employment in tradables in the developing economy to increase technological growth and a higher share of employment in the nontradable sector in the developed economy to complement the imports of tradable goods). Under the chosen parameterization of the model, the lower cost of borrowing due to the movement in the real exchange rate is more than enough to offset the higher cost of borrowing due to the change in the interest rate (all relative to the laissez-faire setting), such that the developed economy borrows tradable goods from abroad and enjoys a higher level of welfare from additional consumption over the short-term.

The ability of the developing country to run a current account surplus in this setting is an important distinction relative to the model presented in Chapter 1,

wherein a small open economy with a similar productivity externality in the production of tradable goods would not be expected to run a surplus using a comparable calibration. The reason for this difference is fundamentally driven by the role of physical capital in Chapter 1. In a model with physical capital as a secondary factor of production and free movement of capital both internationally and domestically between sectors, it's a well-known result that relative prices, including the real exchange rate, will be constant (See Obstfeld and Rogoff (1996)). As such, a small open economy's perceived payoff from lending a unit of tradable income today would be approximately $\bar{q}(1 + \bar{r})$ units of real consumption one year in the future. Since both \bar{q} and \bar{r} are unresponsive to the imposition of capital controls, the only factor determining whether the economy will borrow or lend is the elasticity of intertemporal substitution ($1/\theta$), which according to Chapter 1 is too low within generally accepted ranges to motivate lending. However, if the model presented in this chapter were restricted to the analysis of a single small open economy facing a fixed international rate of interest (calibrated so as to continue matching the empirically observed frontier growth rate of 1.8%), it would still be possible to observe a developing economy current account surplus for values of the elasticity of intertemporal substitution as low as 0.5 and beyond, while maintaining the same technology growth parameters (i.e., γ_0 and γ_1 in (2.9)). Furthermore, the movements in the endogenous interest rate are fairly tame – percentage-wise – relative to those of the real exchange rate, as can be seen in Figures 2.6 and 2.7. Therefore, the model presented in this chapter suggests

that any attempt to match the experience of the Chinese economy via mercantilist policy ought to incorporate some degree of exchange rate depreciation (a rise in q), which increases the incentives for a growing economy to lend its output to foreign economies.

Returning to the discussion of the evolution of the developed economy under capital controls, the early foreign asset imbalances in Figure 2.4 continue for roughly the first 100 years or so of the transitional period, during which time the developing country's technology has grown much more quickly relative to its *laissez-faire* evolution, as seen in Figure 2.1. Because of this tremendous growth in productivity, output has increased substantially, thereby allowing for higher consumption. As the developing country's consumption quickly grows from its initially repressed level, the equilibrium international interest adjusts downward, as suggested by the relationship in (2.44). Concurrently, as the developing country's level of technology approaches the frontier level its growth rate starts to fall, and the interest rate begins converging to its long-run steady-state level, such that it always stays below its *laissez-faire* level, as seen in Figure 2.7, regardless of the relatively lower level of consumption in the developed economy in later years. Because the developing country's technology is nearer to the frontier, the government's incentive to reallocate labor to the tradable sector diminishes. Over time, the country starts to run down its accumulated foreign assets as its consumption rises. Eventually, its motivations become more and more similar to its *laissez-faire* self, as it begins to borrow again from the developed econ-

omy and the current account balances reverse signs. Interestingly, this may portend radical shifts in the Sino-American economic relationship at the heart of the global economy in coming decades.

As shown in Figure 2.2, the developed country eventually consumes at a lower level relative to the laissez-faire setting. This occurs for two reasons: First, the developed country's ability to borrow early on allows it to achieve a flatter profile relative to laissez-faire by intertemporally shifting consumption to earlier periods. Second, as the developed economy assumes a role as net lender to the rest of the world, it does so while earning relatively less income on its assets due to both a *lower* interest rate and a *much lower* volume of capital outflows to the developing economy, as seen in Figure 2.4. That is, after just the first 25 years or so the developing economy has managed to nearly triple its productivity, and so the government begins to ease off on its efforts to direct labor into the tradable sector by keeping consumption down as the economy's desire to smooth consumption takes over as its main guiding motive. Thus, consumption continues to rise as the developing country begins to run down its accumulated level of assets. By the time the current account balances reverse and the developed economy starts to lend capital abroad as in the laissez-faire setting, the developed economy has caught up to roughly half the frontier level, and there remains much less future output growth to borrow against. As a result, the developing economy ends up with a net foreign asset position in the long-run steady state of only about -400% of GDP, as opposed to roughly -2000% under laissez-faire.

In other words, the developed economy takes in less interest income because it both earns less on every foreign asset due to lower interest rates and it just accumulates far fewer interest-bearing assets.

As such, the developed economy is unable to support as high a level of long-run consumption and endures a lower level of latter-period welfare (in contrast to its relative welfare premium during the early years). As the developing country is able to adopt new technologies very quickly early on, it only finances the developed country's early inflated consumption for a short period of time. In sum, the latter years' depressed consumption due to low interest income very slightly dominates the developed economy's early years of high consumption, in terms of discounted utility. As such, the developed economy suffers a very small 0.6% welfare *loss*⁷ due to the developing economy's implementation of capital controls.

On the other hand, the developing economy clearly improves its lot by exploiting the extant productivity externality, such that it exhibits a relatively huge 14.5% welfare gain under mercantilist government intervention. Noticeably, the model also predicts that the country's initial real exchange rate will be undervalued by a whopping 44.2% relative to the rate that would have prevailed in the absence of government involvement. While the welfare loss experienced by the developed country is relatively very small, it may provide reason for the developed economy to feel aggravated by its neighbor's use of mercantilist policy and argue for more liberalized relations. At the

⁷Welfare gains/losses are expressed in terms of percentage changes to the level of permanent consumption required to equate welfare between the two states of the world economy.

same time, however, political considerations may make taking any action very difficult as the country's early welfare higher is relatively high, potentially delaying any calls for reform until decades after the policy was first implemented by the developing country. Regardless, the results suggest that a technologically advanced economy may construe the use of capital controls as a "beggar-thy-neighbor" policy.

2.4 Three Countries

I now consider a world with three economies: a developed economy at the global technological frontier ($i = 1$), a developing economy with an initial productivity level of 0.1 relative to the frontier ($i = 2$), and a second developing economy with a slightly more advanced initial level of productivity of 0.2 relative to the frontier ($i = 3$). First, I consider a laissez-faire version of the world economy. Second, I allow for both developing countries to use capital controls. Third, I assume that *only* the least technologically country uses capital controls. I compare the outcomes of these three versions of the model, giving special consideration to the welfare effects on the developed and second-most developed countries. In this context, we might consider Country 3 as playing the role of "Brazil", that is a second developing economy similar in size to the first, which has implemented capital controls (e.g. "China"). Like "China", "Brazil" is also attempting to catch-up to a third similarly-sized but technologically-advanced economy (e.g. "The United States"), while deciding whether

or not to implement its own capital control policies.

2.4.1 Laissez-faire

Again considering the extreme case in which $\alpha_i = 1$ for $i = 1, 2, 3$, one can derive the following closed-form expression for the equilibrium international interest rate in a laissez-faire setting:

$$r_t = \left(\frac{\theta\phi(\dot{a}_{2t} + \dot{a}_{3t})}{c_{T1t} + c_{T2t} + c_{T3t}} \right) + \theta g + \rho, \quad (2.45)$$

which is again a decreasing function in the values of tradable consumption in each country, and converges to a long-run steady-state value of $\theta g + \rho$ as the levels of technology in the two developing economies approach the global frontier. If both developing countries were to grow at the same rate as the developed economy, g , then all countries would behave as if in financial autarky.

The intuition behind the development of the world economy in a laissez-faire setting is identical to that of the two-country setting. In a three-country world, the two developing economies both have a relatively stronger desire to borrow against their higher future income than the developed economy as they both grow at faster rate due to catch-up to the technological frontier, leading them to both amass large stocks of net foreign debt to the developed economy. After an initial period in which the vast majority of their tradable consumption is imported from abroad, each devel-

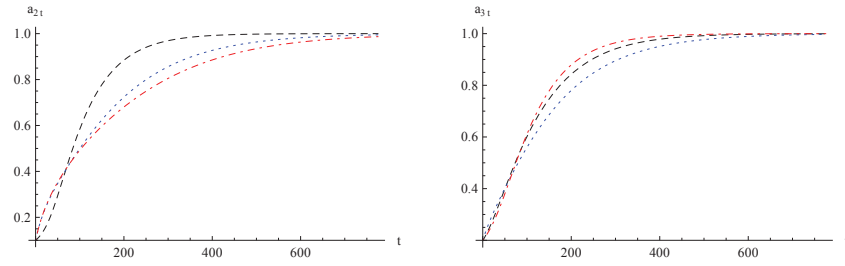


Figure 2.9: Technology paths. Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

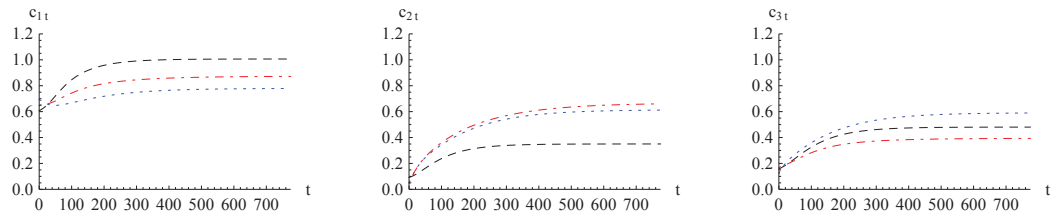


Figure 2.10: Consumption paths. Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

oping country goes through a fairly rapid transformation wherein labor moves into the tradable sector to produce goods used to meet the interest obligations on their accumulated debts.

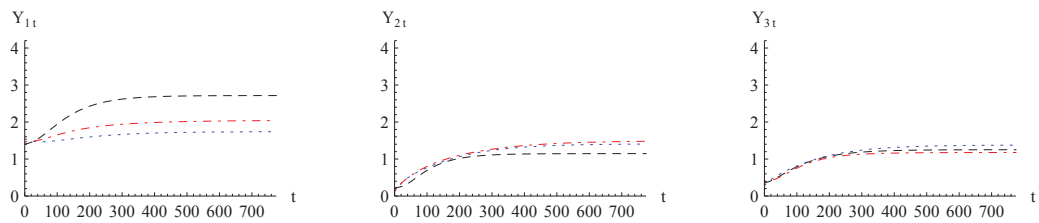


Figure 2.11: Output paths. Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

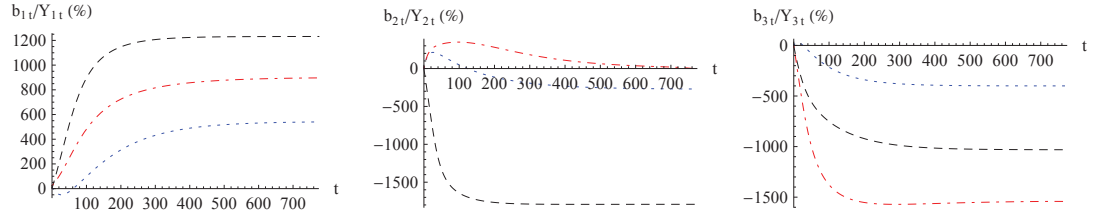


Figure 2.12: Net foreign asset paths (%). Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

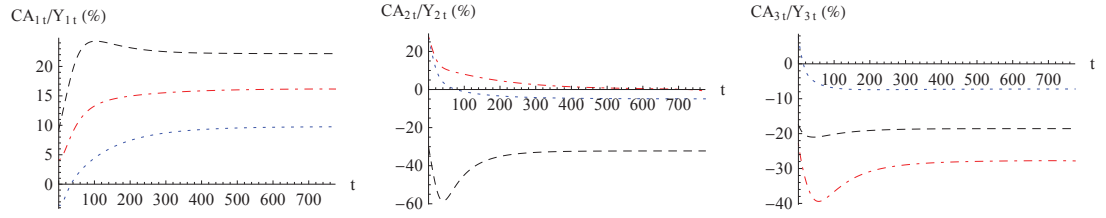


Figure 2.13: Current account paths (%). Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

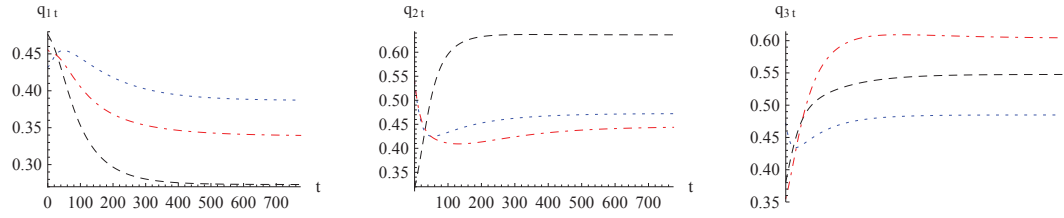


Figure 2.14: Exchange rate paths. Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

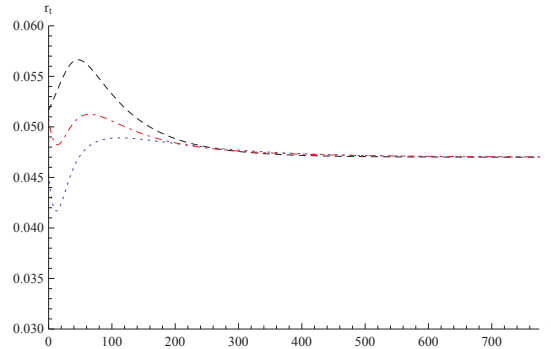


Figure 2.15: Interest rate paths. Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

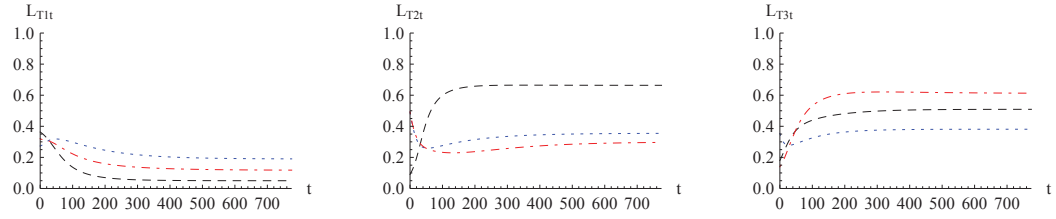


Figure 2.16: Labor share paths. Laissez-faire - Black dashed. Capital controls - Blue dotted. Mixed Policies - Red dash-dotted.

2.4.2 Capital Controls

2.4.2.1 Two Countries with Capital Controls

Now suppose that both of the developing economies institute capital controls and their respective governments actively manage the flow of income within their economies. Again, the evolution of the world economy is very similar to that of the two-country case, in that the two developing countries behave together in a manner equivalent to that of the single developing economy in the prior scenario. As before, government action results in repressed consumption levels relative to the laissez-faire setting on the part of both developing economies. The lower levels of tradable consumption coincide with sufficiently higher outputs of tradable goods to run trade balance surpluses with the developed economy. Furthermore, the higher shares of employment in the tradable sectors of both developing economies facilitates a faster rate of technological convergence.

As such, both developing economies enjoy higher welfare as result of faster early growth, with premiums of 12.7% for Country 2 and 2.5% for Country 3. Note that

the welfare gain for Country 3 is significantly lower than that of Country 2, as it starts from a higher initial level of technology and therefore has less to gain from mercantilist policy. Also, as in the two-country setting, both developing countries experience initial real exchange depreciations relative to the laissez-faire case due to the higher relative domestic output of tradable goods. Country 2's exchange rate is initially undervalued by 41.1% and Country 3's by 19.3%.

In contrast, the developed economy again experiences an initial period of relative higher consumption financed by loans from the developing economies that later gives way to a period of asset accumulation, albeit at lower interest rates than in the laissez-faire setting as shown in Figure 2.15. Overall, the welfare loss from receiving lower interest income in this later period dominates the welfare gains from the early period of higher consumption, such that the developed economy suffers a total welfare loss of 1.1%. Seeing as how the total populations of each country have been assumed to be equal, the minor welfare loss of the single developed economy is more than compensated for by the welfare gains of the two developing economies, implying that total world welfare has increased as a result of capital control policies.

2.4.2.2 One Country with Capital Controls

Finally, I consider an alternative setting in which only the developing economy with the lowest initial level of technology (Country 2) makes use of mercantilist capital controls while the other developing economy (Country 3) and the developed economy

(Country 1) maintain laissez-faire environments. Overall, the addition of Country 3 as a second developing economy without the benefit of government-directed resource reallocation allows the developed economy to behave more like itself in pure laissez-faire settings by providing loans to the developing world and enjoying the additional interest income over time while still accommodating Country 2's growth-enhancing policies.

The easiest way to understand the evolution of the world system in this context is by focusing on the behavior of Country 3. In both the current context and the baseline laissez-faire setting, the country does not place restrictions on capital flows nor does the government intervene in any way, so comparing the country's evolution in these two cases is insightful. Because of the government's actions in Country 2, that economy's level of consumption grows very rapidly from an initially repressed level, thereby putting downward pressure on the equilibrium international rate, similar to the expression in (2.45) (or in other words, the additional supply of loanable funds from Country 2 pushes down the cost of borrowing in the short-run). Crucially, as shown in Figure 2.15, the interest is always below the rate that would prevail in a pure laissez-faire world. This lower interest rate affects Country 3's behavior in two ways: 1) income and substitution effects, and 2) wealth effects.

Since Country 3's primary motivation is to borrow against its higher future output to smooth its consumption profile, it ends up borrowing from the rest of the world and accumulating a negative net foreign asset position. Therefore, because of the lower

interest rate, Country 3 feels at every point in time as though it has relatively more income (because the interest payments on its accumulated debt are lower) and that the cost of additional borrowing is relatively cheap. As such, it accumulates an even larger stock of debt than it did in the pure laissez-faire world, as shown in Figure 2.12. Together, these effects are welfare-improving as they allow for a relatively smoother path of consumption over time, including an initially higher level in the short-run, as shown in Figure 2.10.

At the same time, however, Country 3 experiences wealth effects in two different ways. First, the persistently lower interest rate increases the total present-discounted value of income over the economy's whole time horizon. Second, the total amount of output the country produces over its time horizon is lower. This is because of the effect that borrowing has on the sectoral composition of the economy. Because the country perceives debt as being very cheap, an even lower share of labor is allocated to the tradable sector as domestic production is displaced by imported goods. Moreover, the low cost of borrowing enables the economy to maintain its high current account deficit for a longer period of time, thereby keeping employment in the tradable sector lower for longer as shown in Figure 2.16. As such, Country 3's rate of technological progress is initially retarded for decades relative to the pure laissez-faire world economy, as seen in Figure 2.9. Ultimately, this negative wealth effect dominates all of the positive effects of facing a lower international rate of interest. Overall, despite the favorable lending terms, Country 3's slower initial growth sufficiently reduces its lifetime output

so as to leave it worse off, with a welfare *loss* of 0.4%. Also, unlike the previous section, the actions of Country 2 cause Country 3's real exchange rate to *appreciate* by 7.2%.

In summary, it's not surprising to see that Country 3's welfare has declined from when it was also using capital controls to correct its externality. What perhaps is surprising, however, is that its welfare in the present setting is even *lower* than under complete global laissez-faire. In other words, Country 2 doesn't just "miss out" on an opportunity to make itself better off through employing its own mercantilist policies, but Country 1's use of capital controls actually makes Country 2 even worse off than if Country 1 hadn't deviated from laissez-faire. Thus, even for a country starting from a relatively better position (i.e. a higher initial level of productivity), the use of capital controls by a fellow developing economy could be seen as a threat to another developing economy's well-being.

Country 2 behaves very similarly to itself in the previous scenario. The government's action to redirect domestic income initially lead to a low level of tradable consumption and, by the relationship in (2.17), a high level of tradable output, which supports a trade surplus in the short-run. Because Country 3 does not also run a trade surplus, there is less downward pressure on the international interest rate. In a sense, the lack of "competition" in the export market from Country 3 allows Country 2 to enjoy a relatively higher level of interest income on its assets and thereby a slightly higher level of consumption. Again, the higher allocation of labor to the tradable sector exposes more of the country's human capital to international best

practices and productive technologies, allowing the country to adapt and catch-up to the global frontier more quickly. Overall, the country experiences a welfare gain of 13.0% relative to the laissez-faire setting, which is an even higher premium than in the previous scenario in which Country 3's concurrent use of capital controls led to a relatively depressed interest rate. Also, as in the previous section, Country 2's real exchange rate depreciates by 41.2% relative to the pure laissez-faire setting. One notable difference from the previous section, however, is that Country 3's strong demand for capital inflows (a factor absent in the two-country setting) allows Country 2 to maintain a positive current account balance for a much longer period of time than in any other setting.

In regards to the developed economy, it's important to keep in mind that its economy is also growing over time, and as such it would like to borrow against its future output in order to smooth its consumption profile. However, since Country 3's growth rate is so much higher, its desire to borrow is very strong, such that Country 1 ends up loaning it capital. However, because of its government's intervention, Country 2 is also willing to partially meet Country 3's demand for loanable funds, such that the developed economy doesn't end up exporting as many tradable goods as it would in the pure laissez-faire setting. As a result, Country 1 can achieve a relatively smooth consumption path, including a higher level of consumption in the short-run. Eventually, as Country 2 approaches the technological frontier, its consumption smoothing motive overwhelms its technological growth motive, such that it, too, desires to borrow

from the developed economy. However, due to the higher levels of global consumption (and the convergence of r_t to its steady-state level), the international rate of interest is lower than in the laissez-faire setting, causing a fall in the long-run level of interest income on foreign assets that the developed economy receives. However, the level of interest income is relatively higher than in the setting with both developing countries using capital controls. By comparison, the welfare-*gain* from higher consumption in the short-run isn't as great as in the previous scenario with both developing countries using capital controls (Section 2.4.2.1), but the welfare-*loss* from lower interest income is also smaller, resulting in a clear overall welfare premium. Ultimately, however, the relative size of these two effects in comparison to the laissez-faire setting is somewhat sensitive to the precise calibration of the model. Using the parameters presented in Section 2.2, the developed economy ends up with a very small welfare *loss* of 0.4% relative to the laissez-faire case, implying that the developed economy is best off when neither developing economy exercises capital controls. However, under alternative parameterizations, it's also possible to observe a slight welfare gain relative to laissez-faire (e.g. if the labor elasticity of output is sufficiently low).

Therefore, also taking into account the results from the two-country setting, a developed economy may be threatened or pleased by the use of capital controls in developing countries, depending on the exact number of participants in the international financial market and overall configuration of the global economy. But, under the most plausible possible parameterization, it seems most likely that the developed economy

would be subject to welfare losses when its neighbors decide to implement mercantilist policy, with the important caveat that in any case the developed economy's welfare gains or losses are rather small, and the potential political costs of attempting to dissuade another government from pursuing a mercantilist agenda may outweigh any other considerations.

2.5 Conclusion

In summary, the model presented in this chapter demonstrates that developing economies may be “left behind” if they do not also make use of mercantilist policy to compete with other developing economies. In other words, one might consider the use of capital controls to be a “beggar-thy-neighbor” in the global economy. On the other hand, developed economies may be concerned or pleased with the use of such policies depending on the exact configuration of the world economy.

Furthermore, relative to Chapter 1, the model presented in this chapter makes it much easier to justify positive current account balances on the part of developing economies making use of mercantilist policies, such as capital controls. More specifically, the endogeneity of international interest rates requires much less extreme values of the elasticity of intertemporal substitution to achieve positive current account balances on par with or exceeding those of China during the early 2000s.

Finally, it's interesting to note that the gains to developing economies from using

capital controls by far trump any potential losses from other countries, developed or developing. Thus, the use of such policies should be encouraged by any institutions whose goal is ostensibly to increase the overall global level of welfare. Furthermore, the model abstracts from any potential dynamic benefits a country might gain from the rise a more robust and healthy trading partner (such as might be the case in a model with heterogeneous resources and/or multiple tradable goods).

Chapter 3

Tradable and Nontradable Sectoral Productivities: Exports and Convergence

As the phenomenon of “globalization” has progressed over recent decades, there has been substantial interest in the effects of exposure to international markets on economies, especially whether greater openness may contribute to faster growth. An influential study by Rodrik (2008) found a statistically significant relationship between a country’s degree of real exchange rate undervaluation and economic growth, suggesting that countries could improve their growth prospects by taking advantage of special characteristics inherent in those sectors of production focusing on tradable goods. Such ideas are not only interesting in their own right, but have also often

served as motivating assumptions in theoretical models attempting to explain related economic developments. In particular, a growing body of work has sought to explain recent buildups in developing countries' stocks of foreign reserves by relying on varying assumptions about the relationship between tradable-goods production and output growth. However, empirical evidence of such connections has been mixed. This paper contributes to the empirical literature in this area by using a novel firm-level approach to sectoral productivity estimation in order to test the commonly-assumed relationships between productivity growth and the size of the economy's tradable sector. Using a uniquely-constructed panel data set across countries and years in a structural VAR analysis, I find that higher employment in the tradable sector and/or exports contribute to higher productivity growth.

When it comes to long-term economic growth, Klenow & Rodriguez-Clare (1997) and Easterly & Levine (2001) have persuasively argued that factor accumulation alone is not sufficient to explain most of the variation across countries' levels of output. As such, most of the discussion in the area of trade-related growth has centered around the determinants of total factor productivity (TFP). The influential work by Rodrik (2008) not only found that real exchange rate undervaluation was correlated with economic growth (and additional analysis by Korinek and Serven (2010) confirmed a similar relationship between undervaluation and TFP), but that the size of a country's industrial sector could be construed as a channel whereby this relationship operates.

Since most industrial output is inherently internationally tradable, Rodrik sug-

gested that the tradable sector benefits from a depreciated exchange rate because it exhibits certain special characteristics: e.g. bad institutions that levy prohibitively high taxes on tradable goods and/or a relative abundance of market failures. In particular, many others have focused on the possibility that firms in the tradable sector fail to internalize the existence of positive productivity externalities that result from their exposure to international markets. The basic intuition is that successful competition with international firms requires adopting global best-practices and cutting-edge technologies in order to become comparably efficient.

Recently, many authors have used these notions as central assumptions underpinning their theoretical models that explain the potential benefits of “mercantilist policies” associated with the accumulation of foreign asset reserves. As examples, Chapters 1 and 2 and Michaud & Rothert (2014) assume that economies with higher shares of employment in the tradable sector benefit from faster rates of technological adoption due to greater exposure of human capital to efficient international competition (a type of “learning-by-doing” (LBD)). Benigno & Fornaro (2014) assume that productivity is increasing in the quantity of intermediate goods imported from abroad for use in domestic production. Korinek and Serven (2010) assume the existence of technological spillovers from investment in capital that offer relatively greater benefits to the tradable sector (“learning-by-investing” (LBI)). More broadly, Frankel & Romer (1999) show a general relationship between international trade and economic growth (or “learning-by-exporting” (LBE)). While the exact nature of these relation-

ships may differ (and so too do the optimal policy responses, as shown in Aizenman & Lee (2010)), the common theme is that a country ought to be able to derive significant productivity/technology growth premiums through focusing on the development of the tradable sector.

However, empirically proving the existence of a relationship between productivity growth and activities in the tradable sector has proven very difficult. On the “micro” side, there are inherent difficulties in accurately estimating firm-level productivity due to the endogeneity of factor-input decisions (i.e. managers observe TFP when allocating capital and labor while econometricians do not) and firms exiting markets over time (perhaps due to low TFP, meaning their absence from observed data may result in biased estimates). Important econometric contributions from Olley & Pakes (1996) and Levinsohn & Petrin (2003) introduced two-step proxy-variable approaches to addressing these issues, and Wooldridge (2009) further improved upon these models with a more robust GMM approach.

Moreover, even if firm-level TFP is accurately estimated, there may be significant difficulty in detecting a relationship between productivity and exporting. While there has been substantial evidence that exporting firms tend to have higher levels of productivity in many countries (e.g. Kraay (2002) in China; Clerides, et al (1998) in Colombia, Mexico, and Morocco, Blalock & Gertler (2004) in Indonesia; Aw, et al (2000) in South Korea and Taiwan; Damijan, et al (2004) in Slovenia), the direction of causation is unclear. That is, as demonstrated in theoretical models by Melitz

(2003) and Helpman, et al (2004), the firms that are already the most productive may choose to export because they are the most capable of competing successfully in the international market. Thus, empirical studies have struggled to identify a relationship free of this self-selection bias. In other words, does higher productivity lead to more tradable-sector activity, or does greater activity in the tradables sector contribute to higher productivity? More recent studies using various econometric methodologies to correct for self-selection bias have been able to identify a relationship running from exporting to productivity. For example, De Loecker (2004) uses a matching approach to find significant boosts to productivity after entering the export market, and Park, et al (2010) make use of the recent global financial crisis as an exogenous shock to export demand in order to identify a similar result in Chinese firms.¹ Furthermore, the benefits to society of an individual firm increasing its efficiency via international exposure may be overshadowed by potential spillover effects resulting from that firm's influence on other domestic firms. Thus, a higher-level approach may be necessary in order to fully understand the entire relationship between the production of tradable goods and productivity.

On the “macro” side, the traditional income accounting methodology of estimating TFP as a residual from an aggregate production function requires the assumption that such a function realistically exists. The difficulties in motivating the use of an aggregate production and the specific underlying assumptions it may require are

¹See also Blalock & Gertler (2004) for additional evidence of LBE effects and Wagner (2007) for an overview of this literature.

well-documented (See Fisher (1969) for a critical analysis and, more recently, Felipe & Fisher (2003) for an overview of the primary issues). Even Robert Solow in his seminal work on economic growth (1957) stated, “it takes something more than the usual ‘willing suspension of disbelief’ to talk seriously of the aggregate production function.” So, by extension, one ought to be similarly dubious of any estimates of TFP emanating from the use of an aggregate production function. Additionally, the use of economy-wide estimates of TFP obscures the relative contributions of different segments of the economy. In particular, if we hope to learn of the effects of the tradable sector on productivity, it may be enlightening to focus on the productivity of the tradable sector itself, rather than to expect those effects to show up clearly in an aggregate measure of TFP across all sectors of an economy. Moreover, allowing for disaggregation allows us to better address additional questions of interest discussed below.

This paper addresses these issues by using a combination of micro- and macro-level approaches. First, firm-level TFP is estimated using a panel data set (similar to Imrohoroglu & Tuzel (2013) and Fons-Rosen, et al (2013)) with representation from 99 developed and developing countries, using the procedure outlined in Olley & Pakes (1996) to control for the issues of endogenous factor selection and firm exit. Doing so allows for aggregated estimates of TFP across sectors and for the economy as a whole by taking the average across firms (weighted by value-added) without needing to specify an aggregate production function. Furthermore, looking at these aggregate

TFP measures allows for detection of broad productivity spillover effects external to individual firms as well as consideration of sector-specific effects.

Using this data, and unlike most previous work which subjectively categorizes output as tradable or nontradable, I use the World Input-Output Tables to measure the export-intensity of 34 industries and objectively define each industry's output as being "tradable" or "nontradable" accordingly. Also, I consider whether higher levels of export intensity within industries is correlated with higher levels of TFP. Next, having sector-specific TFP estimates allows me to test the common theoretical assumption that TFP in tradable sectors grows more quickly than in nontradable sectors. Additionally, sector-level TFP estimates allow for an updated empirical test of the Harrod-Balassa-Samuelson effect. Furthermore, I provide evidence of cross-country convergence in TFP, especially in the tradable sector.

In the main analysis, I use the aggregate TFP estimates to test for statistical relationships between industrial labor shares (as a proxy for overall tradable-sector employment), aggregate exports, real exchange rates, and productivity growth in a structural panel VAR analysis. Using a VAR regression allows for consideration of simultaneous feedback effects not controlled for in other previous econometric analyses, such as Rodrik (2008) and Chapter 1. I present evidence that structural shocks to tradable-sector labor shares and exports do indeed have positive effects on TFP growth, as assumed in the theoretical literature referenced earlier. Finally, I give consideration as to whether there are significant differences in these results between

developed and developing economies, as might be explained by the existence of a “global technology frontier,” finding mixed results depending on the source of the externality and the measure of TFP used.

I proceed in Section 3.1 by discussing the data used to estimate firm-level TFP, followed by details of the estimation procedure in Section 3.2. I then present basic results in Section 3.3, followed by the main results of the VAR analysis in Section 3.4, then offer some concluding remarks in Section 3.5.

3.1 Firm-level Data

The main sources of data used in the estimation of firm-level TFP are Compustat North America (1950-2013) and Compustat Global (1987-2013), which provide consolidated data for publicly-listed firms. I designate firms as representing specific countries based on the location of their headquarters, as the country in which a firm is reported as being incorporated may be completely unrelated to the firm’s actual primary location of production activity (e.g. many large multinational corporations are officially incorporated in Caribbean countries for tax purposes). Furthermore, many firms may be listed on US stock exchanges, primarily for purposes of equity financing and brand exposure and reasons unrelated to operations actually occurring in the US. Of course, this is a first-approximation at best, since many large publicly listed have operations spanning multiple countries. By this procedure, I find that Compustat

North America covers 34,386 firms from 22 countries and Compustat Global covers 38,369 firms from 104 countries. However, after cleaning the data (discussed below) and dropping missing observations, coverage drops to 5,538 firms from 14 countries in Compustat North America and 14,945 firms from 92 countries in Compustat Global (this is primarily because of missing wage data, which is necessary for the estimation of TFP).

For the most part, I follow Imrohoroglu & Tuzel (2013) in estimating firm-level total factor productivity. For each firm, value added (y_{it}) is measured as “operating income before depreciation and amortization” less “staff expenses - wages and salaries.” The number of employees at each firm is used as a proxy for the size of labor (l_{it}). A firm’s age (g_{it}) is proxied by the number of years since it first appeared in the Compustat database. Capital stocks (k_{it}) are calculated by using data on “property, plant, and equipment” and following the method of Hall (1990) using accumulated depreciation to estimate the average age, smoothed over three years, of all capital vintages owned by each firm and deflated accordingly (in certain cases when the average age is very high, the oldest available deflator is used). Finally, investment (ι_{it}) is measured by the “capital expenses” data from Compustat.

Data reported by each firm are first converted to real 2005 local currency values using GDP deflators from the World Bank’s World Development Indicators (WDI) and the IMF’s International Financial Statistics (IFS) databases, then converted to 2005 US dollars using average exchange rates over 2005 from WDI, so that TFP levels

are broadly comparable across countries.

3.2 TFP Estimation

3.2.1 Firm-level TFP

Due to the limitations of Compustat, observations of intermediate inputs for each firm are unavailable, thus precluding the use of the somewhat more robust empirical estimation procedures outlined in Levinsohn & Petrin (2003) and Wooldridge (2009). Therefore, I follow the approach introduced in Olley & Pakes (1996) by assuming each firm's value-added function can be expressed as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_g g_{it} + a_{it} + \epsilon_{it} \quad (3.1)$$

where a_{it} represents productivity, ϵ_{it} represents natural variation in output unrelated to productivity or the explicitly represented factor inputs, and all variables are expressed in terms of natural logarithms. I assume that firms observe a_{it} before making their factor input decisions, which introduces bias in OLS estimates primarily because of the relationship between labor and productivity. If we assume that capital investment decisions must be made one period in advance, then the stock of capital in period t is a function of the conditional distribution of productivity in period $t - 1$. In other words, we could write the firm's investment decision as a function of the

state variables:

$$\iota_{it} = \iota(a_{it}, k_{it}, g_{it}) \quad (3.2)$$

which we can invert to express productivity in terms of observable variables

$$a_{it} = a(k_{it}, \iota_{it}, g_{it}). \quad (3.3)$$

We can then rewrite the firm's production function as

$$y_{it} = \beta_l l_{it} + \underbrace{\phi_{it}}_{\beta_0 + \beta_k k_{it} + \beta_g g_{it} + a(k_{it}, \iota_{it}, g_{it})} + \epsilon_{it} \quad (3.4)$$

where ϕ_{it} is approximated by a second-order polynomial series in capital, investment, and firm age. This allows for an unbiased estimate of β_l .

Supposing that in every period each firm must make a decision about whether to liquidate its assets and exit the market or continue production in the following period, one can derive the following expression for the expectation of output in period $t + 1$, using the estimated value of β_l :

$$E_t(y_{i,t+1} - \hat{\beta}_l l_{i,t+1}) = \beta_0 + \beta_k k_{i,t+1} + \beta_g g_{i,t+1} + E_t(a_{i,t+1} | a_{it}, \text{non-exit}) \quad (3.5)$$

or

$$E_t(y_{i,t+1} - \hat{\beta}_l l_{i,t+1}) = \beta_0 + \beta_k k_{i,t+1} + \beta_g g_{i,t+1} + \rho(a_{it}, \hat{P}_{it}) \quad (3.6)$$

where \hat{P}_{it} is the estimated probability that a firm does not exit the market in period t , obtained via the probit estimation of an indicator variable for exiting the market on investment, capital, firm age, and their squares and cross products. I then use these probabilities to estimate the following equation via nonlinear least squares:

$$y_{i,t+1} - \hat{\beta}_l l_{i,t+1} = \beta_0 + \beta_k k_{i,t+1} + \beta_g g_{i,t+1} + \rho(\hat{\phi}_{it} - \beta_0 - \beta_k k_{it} - \beta_g g_{it}, \hat{P}_{it}) + \eta_{i,t+1} + \epsilon_{i,t+1} \quad (3.7)$$

where $\rho(\bullet)$ is also approximated via a second-order polynomial series. Therefore, the distortion caused by under-performing firms leaving the market is taken into account allowing for unbiased estimates of β_0 , β_k , and β_g . Finally, productivity can be estimated by

$$\hat{a}_{it} = y_{it} - \hat{\beta}_0 - \hat{\beta}_k k_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_g g_{it}. \quad (3.8)$$

Table 3.1 presents estimation results using the procedure above, including bootstrap standard errors and country-dummy variables (not reported).

	β_k	β_l	β_g
Est. Coef.	.474***	.485***	-.022
Std. Err.	.048	.007	.020
95% Conf. Int.	[.379, .569]	[.472, .498]	[-.060, .016]

Table 3.1: Firm production function regression results (***) denotes statistical significance at the 1% level)

3.2.2 Aggregate TFP

Each firm listed in Compustat has a sectoral code (NAICS/SIC/GIC) assigned to it, which I use to categorize it as belonging to one of the 34 industries defined in the World Input-Output Tables (Timmer (2012)). Using these tables, I calculate the export intensity (i.e. total exports divided by total output) of each industry.²

Following De Gregorio et al (1994), I define an industry as belonging to the “tradable” sector if its export intensity is greater than or equal to 10 percent. In contrast to more commonly used subjective categorizations, such as “manufacturing” and/or “agricultural” output, this allows for a more realistic representation of what actually constitutes each country’s tradable and nontradable sectors.

Firm-level TFP estimates are then aggregated by country (“aggregate TFP”), sector (“tradable TFP” and “nontradable TFP”), and industry (“industry-level TFP”) by calculating the average TFP across all firms in the respective category weighted by their value-added. Note that TFP estimates derived in this way suffer from the same problem as traditional aggregate estimates in that their units have no inherently intuitive interpretation, but the goal is not to interpret the values themselves but rather their relationships with other macroeconomic indicators.

All TFP estimates are trimmed at the 1% and 99% percentiles, and any country whose estimates derive from 10 or less firms is dropped from the data set due to

²For countries not represented in the World Input-Output Tables, I substitute the export intensities of the observed country that is the closest match in terms of GDP per capita (as measured in 2005 USD).

insufficient representation. Table 3.2 provides a breakdown of the number of contributing firms per country in the constructed data set. Of course, the breadth of coverage of the Compustat databases does not come anywhere close to representing the entirety of output for any given country in the data set, but the hope is that even a modest degree of representation might be usefully extrapolated to provide broadly applicable insights. At the very least, one might consider the contribution of this paper to be a first-pass exploration of the degree to which a micro-aggregated approach to TFP estimation offers contradictory results to standard macro-based income accounting studies involving a diverse cross-section of economies. An overview of tradable-sector, nontradable-sector, and aggregate TFP estimates across countries is presented in Figure 3.1.

Finally, in order to address possible differences in causal effects between countries at or near the “global technological frontier” and more technologically-disadvantaged countries in the process of catching-up, I categorize each country as “developed” or “developing” depending on their level of income. Rodrik (2008) makes a similar distinction, using the somewhat arbitrary demarcation of \$6,000 US dollars per capita. However, as discussed in Rapetti et al (2012), the precise rule used for the categorization can have significant effects on the overall results. I try to balance the goal of objectivity with the limitations of the data set by using a demarcation of the 75th percentile across all countries in terms of GDP per capita, which amounts to about \$11,000 in 2005 U.S. dollars. This allows for a more intuitive line of separation,

Argentina	17	Lithuania	35
Australia	628	Luxembourg	40
Austria	95	Malaysia	811
Bangladesh	57	Mauritius	15
Belgium	122	Mexico	45
Bermuda	33	Morocco	22
Brazil	115	Netherlands	239
Bulgaria	15	New Zealand	51
Canada	635	Nigeria	59
Chile	23	Norway	291
China	345	Oman	47
Colombia	12	Pakistan	193
Croatia	30	Philippines	144
Cyprus	20	Poland	74
Czech Republic	20	Portugal	65
Denmark	170	Romania	11
Estonia	18	Russia	76
Finland	150	Saudi Arabia	17
France	873	Singapore	580
Germany	831	Slovenia	19
Greece	142	South Africa	280
Hong Kong	1,048	South Korea	20
Hungary	22	Spain	139
Iceland	11	Sri Lanka	148
India	1,420	Sweden	370
Indonesia	338	Switzerland	251
Ireland	95	Thailand	397
Israel	128	Trinidad and Tobago	11
Italy	275	Turkey	127
Japan	15	United Arab Emirates	26
Jordan	11	United Kingdom	2,359
Kenya	20	United States	3,074
Kuwait	30	Vietnam	32
Latvia	29	Zimbabwe	17
Total		17,878	

Table 3.2: Number of Firms Per Country in Data Set.

as well as a decent sample size of developing countries, which are relatively under-represented in the cleaned-up Compustat data (i.e. 16 developing countries and 41 developed countries used in VAR analysis in Section 3.4). A full list of countries

categorized by development group is presented in Table 3.3.

Developed		Developing
Australia	Italy	Bulgaria
Austria	Japan	Brazil
Belgium	South Korea	China
Canada	Lithuania	Colombia
Switzerland	Luxembourg	Indonesia
Chile	Latvia	India
Cyprus	Mexico	Jordan
Czech Republic	Malaysia	Sri Lanka
Germany	Netherlands	Morocco
Denmark	Norway	Pakistan
Spain	New Zealand	Philippines
Estonia	Poland	Romania
Finland	Portugal	Thailand
France	Russia	Vietnam
United Kingdom	Saudi Arabia	South Africa
Greece	Singapore	Zimbabwe
Hong Kong	Slovenia	
Hungary	Sweden	
Ireland	Turkey	
Iceland	United States	
Israel		

Table 3.3: Countries in Data Set Grouped by Development Status

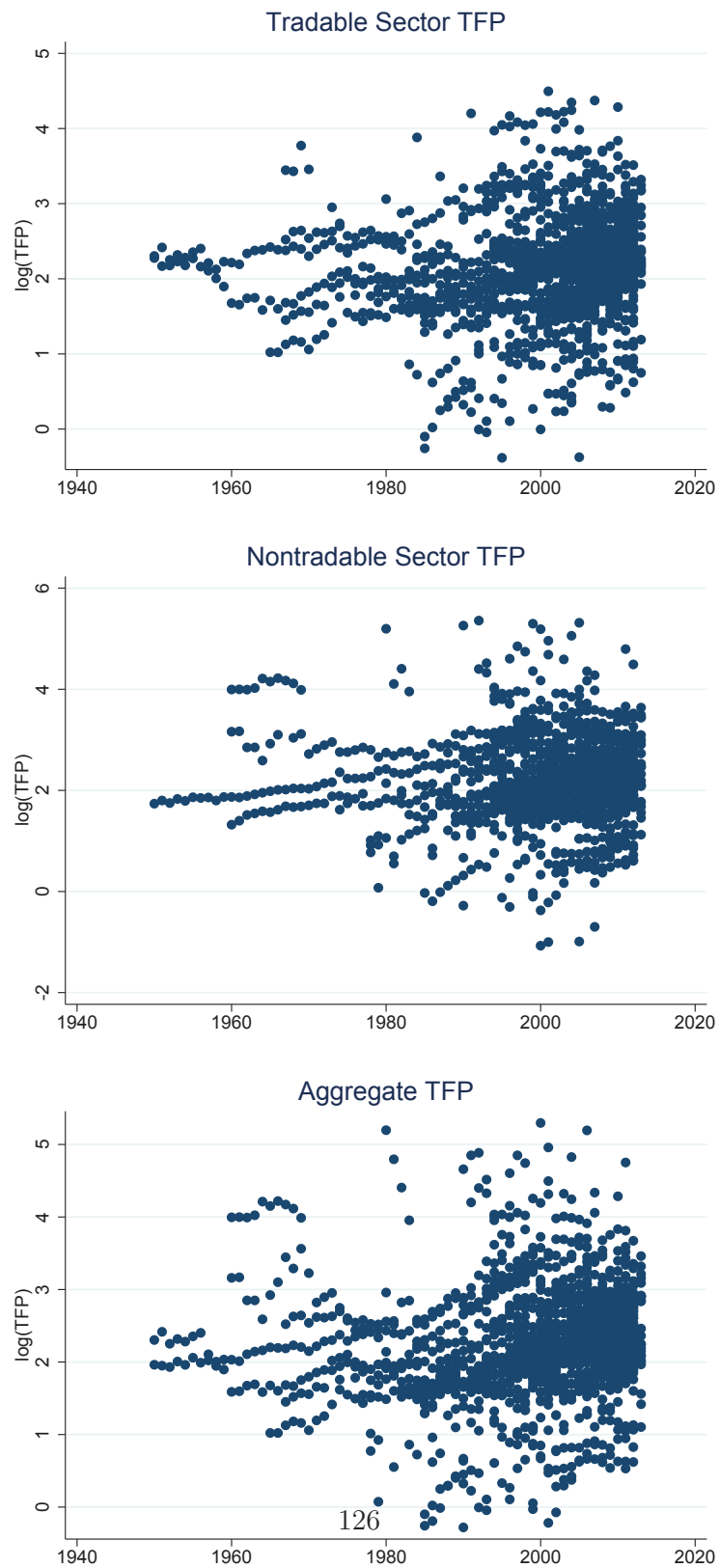


Figure 3.1: TFP Estimates by Country

3.3 Basic Results

In this section, I present basic regression results addressing the following questions: First, at the industry-level, is there evidence of significant learning-by-exporting effects on productivity? Second, does the estimated sectoral TFP data support the Harrod-Balassa-Samuelson effect, which purports a relationship between sectoral productivity growth rates and relative prices? Relatedly, does tradable-sector productivity generally grow faster in most countries than nontradable productivity, as is commonly assumed in theoretical models? Finally, does the data provide evidence of cross-country convergence in TFP? I consider each of the questions in turn below.

3.3.1 Learning-By-Exporting

First, I consider the relationship between export intensity and productivity within industries. Figure 3.2 presents a plot of industry-level TFP growth rates across all countries, industries, and years against those industries' individual export intensities (observations from developed countries are in blue and developing countries are in red). If the idea of learning-by-exporting (LBE) is true, then one might expect that there should be a positive relationship between the amount of effort expended on producing and exporting goods/services and the rate of growth of productivity within those industries. To test this hypothesis, I conduct a panel regression of industry TFP growth rates on export intensities using a full set of dummy variables for individual

countries, industries, and time periods. OLS regression results are presented in Table 3.4.

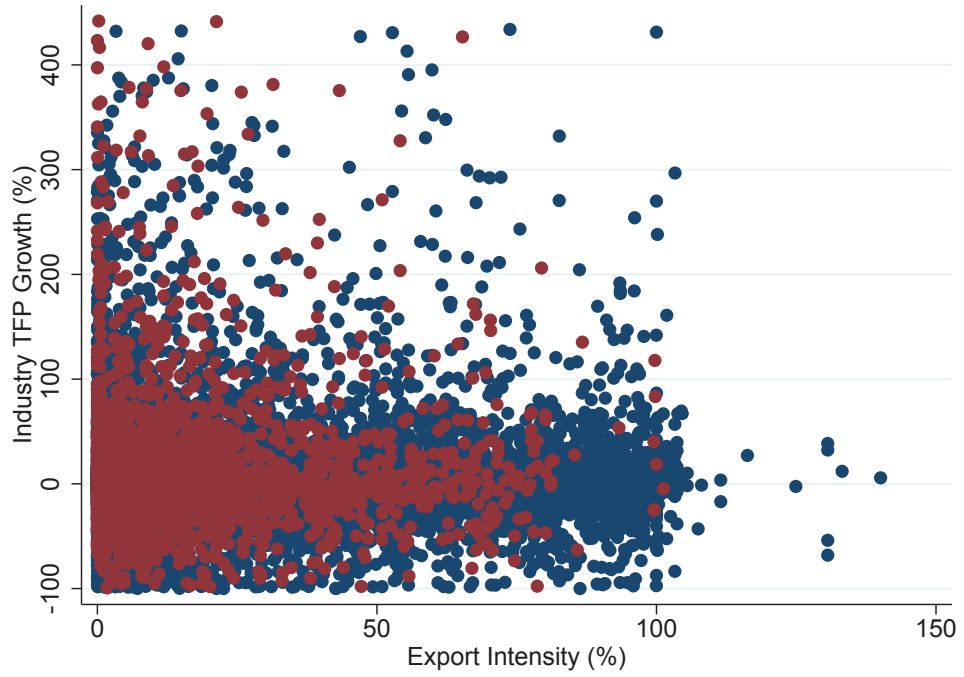


Figure 3.2: Industry-level TFP across all countries and years (Blue Dots: Developed Economies, Red Dots: Developing Economies)

	All	Developed	Developing
β_{exp_int}	.015	.012	.089
Std. Err.	(.027)	(.029)	(.095)
No. Obs.	14,864	12,275	2,527
R^2	.07	.07	.10

Table 3.4: Industry TFP Growth on Export Intensity (as percentages) Regression Results (including dummies for countries, years, and industries)

The estimated coefficient on export intensity is positive and suggests that a 10

percent increase in export intensity corresponds with a 0.15% increase in the growth rate of productivity within a given industry, thus supporting LBE. However, due to the size of the standard error, this estimate is not statistically different from zero. Interestingly, however, the results are substantially different if the analysis is run separately on groups of developed and developing countries. Unsurprisingly, the estimated coefficient for developed countries is very close to the estimate for all countries together, since the bulk of the observations are from developed economies. However, the estimated coefficient for developing countries alone is more than 7 times larger, implying nearly a 0.1% increase in the growth rate of productivity in developing industries that increase their export intensities by 10%. These results would be compatible with the idea of a “global technological frontier”, which posits that developing economies should be able to enjoy faster rates of technological/efficiency growth since they only need to adopt preexisting ideas and best-practices, while developed economies at the frontier will naturally have lower rates of growth since they must focus on the more difficult task of innovating entirely new ideas and technologies.

Of course, this approach ignores the possibility of simultaneity bias resulting from TFP growth rates affecting firms’ exporting decisions. The VAR analysis presented in the next section attempts to address such endogeneity issues and finds somewhat comparable results.

3.3.2 Harrod-Balassa-Samuelson Effect

This section offers additional updated empirical evidence of the Harrod-Balassa-Samuelson effect, following the work of De Gregorio et al (1994) and Asea & Mendoza (1994). To motivate the results in this section, I introduce a simple, real, open-economy model based on Obstfeld & Rogoff (1996) and De Gregorio et al (1994).

Suppose an economy comprises two sectors: tradables and nontradables (denoted by T and N , respectively) featuring the following production functions in aggregate:

$$Y_T = A_T K_T^\alpha L_T^{1-\alpha} \quad (3.9)$$

$$Y_N = A_N K_N^\alpha L_N^{1-\alpha} \quad (3.10)$$

where Y represents output, A is productivity, K is physical capital, L is labor, and α is an income share parameter (tradables serve as the numeraire). Each firm chooses the optimal mix of capital and labor in order to maximize profits given prices, resulting in the following aggregate first-order maximization conditions:

$$\alpha \frac{Y_T}{K_T} = r \quad (3.11)$$

$$(1 - \alpha) \frac{Y_T}{L_T} = w \quad (3.12)$$

for the tradable sector, and

$$p\alpha \frac{Y_N}{K_N} = r \quad (3.13)$$

$$p(1 - \alpha) \frac{Y_N}{L_N} = w \quad (3.14)$$

for the nontradable sector, where r is the real interest rate (which is exogenous because the economy is open to capital flows), w denotes wages, and p represents the relative price of nontradable to tradable goods. Since the production functions are linear homogeneous – and assuming perfect competition in the economy – the zero-profit conditions can be derived using equations (3.11)-(3.14):

$$Y_T = rK_T + wL_T \quad (3.15)$$

$$pY_N = rK_N + wL_N \quad (3.16)$$

Then, log-differentiating (3.15) and (3.16) and substituting in the first-order conditions above results in the following:

$$\hat{A}_T = (1 - \alpha)\hat{w} \quad (3.17)$$

$$\hat{p} + \hat{A}_N = \alpha\hat{w} \quad (3.18)$$

which can be combined to express:

$$\hat{p} = \frac{\alpha}{1 - \alpha} \hat{A}_T - \hat{A}_N \quad (3.19)$$

where $\hat{\cdot}$ denotes a percentage change in a variable. Using the estimates of β_k and β_l in Table 3.1 (from the firm-level production function in (3.1)) as stand-ins for α and rounding up a bit to 0.5, the model relationship above can be expressed more simply as:

$$\hat{p} = \hat{A}_T - \hat{A}_N \quad (3.20)$$

This famous relationship, known as the Harrod-Balassa-Samuelson effect, predicts a positive correlation between high rates of tradable-sector productivity and price levels.

To further compare the productivity differentials to real exchange rates, rather than just domestic relative prices, suppose that overall national price levels P are defined as a geometric average of tradable and nontradable prices with an economy:

$$P = p_T^{1-\gamma} p_N^\gamma \quad (3.21)$$

where p_T and p_N represent the prices of tradable and nontradable goods, respectively, and γ is a parameter defining the relative weight of nontradable goods in determining national prices. Furthermore, suppose that the law of one price holds, such that the

price of tradables goods is the same in every market. Defining the real exchange rate q as the ratio of home to foreign national price levels (where foreign variables are denoted by $*$), the equation in (3.21) implies the following relationship:

$$q = \frac{P}{P^*} = \frac{p_T^{1-\gamma} p_N^\gamma}{p_T^{*1-\gamma} p_N^{*\gamma}} = \left(\frac{p}{p^*} \right)^\gamma \quad (3.22)$$

or in terms of growth rates:

$$\hat{q} = \gamma(\hat{p} - \hat{p}^*) \quad (3.23)$$

Combining (3.20) and (3.23) yields the following relationship:

$$\hat{q} = \gamma(\hat{A}_T - \hat{A}_N) - \gamma\hat{p}^* \quad (3.24)$$

Therefore, holding foreign prices constant, the Harrod-Balassa-Samuelson effect would suggest that relatively higher productivity growth in a country's tradable sector should be correlated with a stronger real exchange rate (a rise in q).

In order to empirically test the validity of the Harrod-Balassa-Samuelson effect, I calculate the differences between tradable-sector and nontradable-sector growth rates in TFP between the earliest and latest available dates and regress these differentials on the percentage change in each country's real effective exchange rate over the same time period (where the relative price of nontradable goods in the model above can broadly be interpreted as a measure of the real exchange rate). Real effective exchange rate

(REER) data from the World Bank's WDI is used in order to capture the overall price relationship between a particular country and all of its major trading partners (where an increase in REER reflects a real appreciation). Regression results are presented in Figure 3.3. The regression results are statistically significant and support the Harrod-Balassa-Samuelson effect, suggesting that a 10% growth premium in tradable over nontradable sector TFP corresponds on average to a 0.33% appreciation in the real exchange rate.

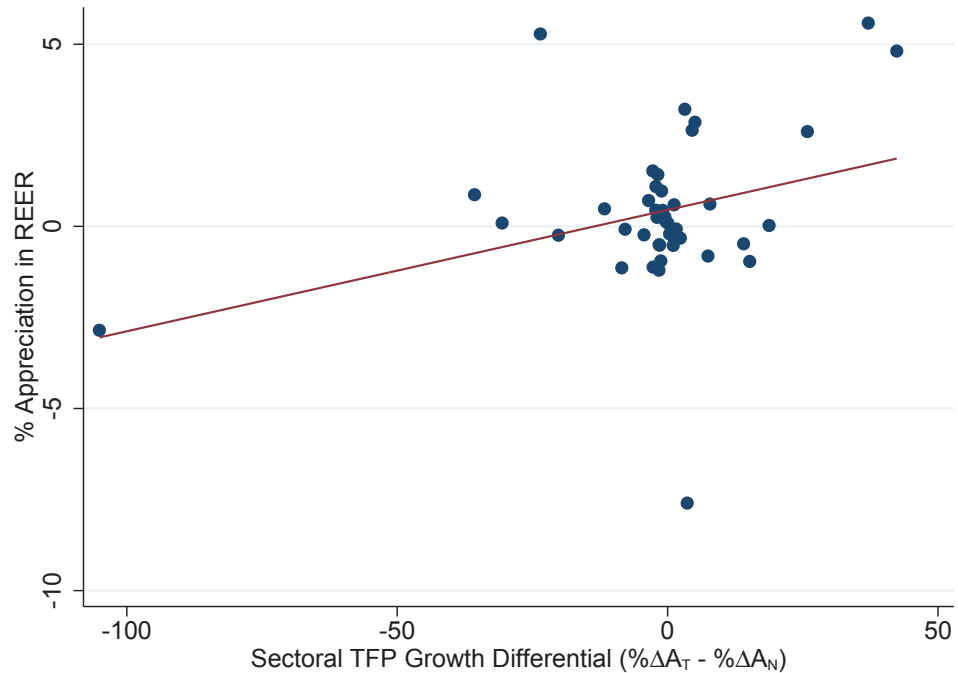


Figure 3.3: TFP Growth Differentials and REER Appreciation

In regards to growth differentials between sectors, contrary to common assumption, there is not strong evidence that the tradable sector always has higher productivity growth than the nontradable sector. The overall median of the differential between

Regressand	Regressors	
$\% \Delta REER$	$(\% \Delta A_T - \% \Delta A_N)$	Intercept
Est. Coef.	.033**	.451
Robust Std. Err.	(.014)	(.310)
95% Conf. Int.	[.006, .061]	[−.175, 1.08]
No. Obs.	44	
R^2	.11	

Table 3.5: Harrod-Balassa-Samuelson Effect Regression Results (** denotes statistical significance at the 5% level).

sectoral growth rates ($\% \Delta A_T - \% \Delta A_N$) is negative at about -1.03%. Among the 44 countries represented in the data set, only 19 have higher productivity growth in the tradable sector over their respective time periods. This result is not completely at odds with other long-term studies of TFP growth. For example, Zhu (2012) finds that a major driver of growth in China has been productivity growth in the agricultural sector equal to or greater than growth in all other sectors. While agricultural output is often inherently tradable, domestic subsidies and other protections to domestic producers in many developed economies often render agricultural output effectively nontradable.

3.3.3 Cross-Country Convergence

Considering that long-term growth has been found to be explained by differences in TFP rather than factor accumulation (see Klenow & Rodriguez-Clare (1997) and

Easterly & Levine (2001)), much thought has been given to whether national TFP levels across countries are converging over time. To add to this literature, I use the data to define a global “technological frontier” and then regress TFP growth on a each country’s lagged distance from the frontier. That is, being farther from the frontier in terms of productivity should correspond to higher future TFP growth rates if countries are all converging to the frontier over time.

However, the best methodology to use to define the “frontier” is not immediately obvious. As such, I consider four alternative specifications: 1) The simplest method is to use the maximum observed value of TFP in every year. Unfortunately, the limitations of the data (in terms of firm representation and entry/exit of firms over time) result in a very unstable frontier from year to year. 2) An alternative is to define the frontier as the line-of-best-fit through the annual max TFP observations, or 3) define the frontier as the trend decomposition from an Hodrick-Prescott (HP) filter of the annual max observations. Both alternatives (2) and (3) have the benefit of resulting in a smoother frontier over time, although the HP-filter trend still exhibits “regressive” periods during which the frontier level of TFP is unintuitively falling (as if some amount of global knowledge were being forgotten). Finally, alternative 4) is an “envelope” approach, wherein the frontier level is assumed to never fall below the previously observed maximum value (and is linearly interpolated between max observations). This approach has the advantage of being nondecreasing and always

equal to or greater than all other observations in each time period.³

A graphical representation of the four alternative frontier definitions is presented in Figure 3.4 in the case of tradable-sector TFP. Table 3.6 presents results from regressing TFP growth on the lagged observation of distance from the defined frontier (in logarithmic form) including dummy variables for individual countries for each of the four definitions of the frontier using tradable-sector TFP. Table 3.7 presents similar results using nontradable-sector TFP estimates.

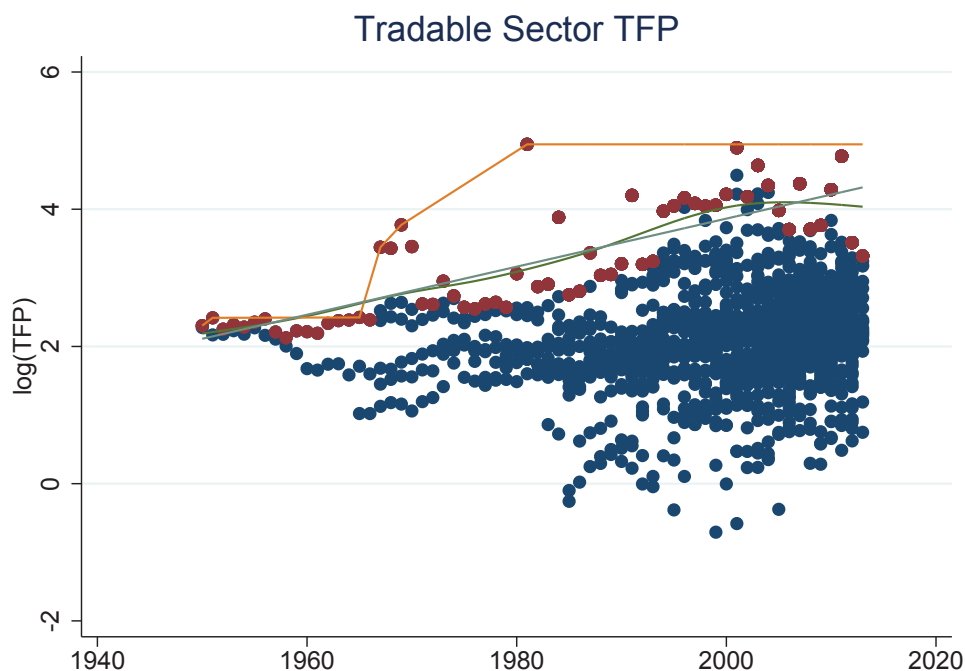


Figure 3.4: Tradable-Sector TFP and Alternative Definitions of the “Technological Frontier” (Annual Max TFP - Red dots, Linear - Blue, HP-Filter - Green, “Envelope” - Orange)

The results are quite robust to the precise definition of the frontier. In all cases, the

³When using the “linear” or “HP-filter” approaches, I drop all observations greater than the defined frontier, as negative distances would be contrary to the concept of a frontier.

	Max	Linear	HP-Filter	Envelope
$\hat{\beta}_{\log(distance)}^T$	.297***	.452***	.465***	.361***
Robust Std. Err.	(.031)	(.044)	(.043)	(.036)
No. Obs.	1277	1237	1242	1277
R^2	.18	.24	.26	.23

Table 3.6: Tradable-Sector TFP Convergence Regression Results (***) denotes statistical significance at the 1% level, includes country dummies)

	Max	Linear	HP-Filter	Envelope
$\hat{\beta}_{\log(distance)}^N$	.210***	.368***	.370***	.318***
Robust Std. Err.	(.027)	(.043)	(.043)	(.036)
No. Obs.	1150	1113	1116	1150
R^2	.13	.21	.21	.20

Table 3.7: Nontradable-Sector TFP Convergence Regression Results (***) denotes statistical significance at the 1% level, includes country dummies)

coefficient on lagged distance is positive and highly statistically significant, suggesting that being farther from the frontier is associated with “catching-up” in subsequent periods. On average, an increase in distance from the frontier of 1% is associated with an increase in subsequent TFP growth of around .4%. This result coincides with previous studies of tradable sector TFP convergence, such as that of Dollar & Wolff (1988). Perhaps most interestingly, the estimates of convergence rates are also positive and highly significant for nontradable TFP, albeit lower than those of tradable-sector TFP convergence. There are a few different possible interpretations of this result. First, a weak conclusion would be that technologies and best-practices are

simply more easily transmitted internationally through the tradable sector relative to the nontradable sector. A second more extreme interpretation would be that there are significant productivity spillover effects from the tradable sector into the nontradable sector. However, this second conjecture requires the strong assumption that the physical trade of goods across borders is the only channel whereby knowledge may be transmitted internationally. Despite the fact that the nontradable sector does not directly interact with international producers, in the neoclassical tradition it is difficult to believe that an entire sector of production could be completely isolated from the flow of ideas except where they flow indirectly via domestic intermediaries. In any case, both ideas reinforce the idea that “mercantilist” policy may have a role to play in boosting overall economic growth by specifically fostering tradable-sector growth, relying on its faster rate of technological adoption as well as spillovers into other sectors (if they exist) to fuel growth in the economy at-large at a relatively faster pace.

Another way to view the differences in sectoral productivities is to consider the relationship between the relative levels of the productivities of the tradable to nontradable sectors and overall economic development as represented by GDP per capita. Observations across all countries and time periods are presented in Figure 3.5, and OLS regression results of the relative productivities on GDP are presented in Table 3.8 (using country-level dummy variables). As can be seen, the estimated coefficient is positive, suggesting that more developed countries tend to have relatively higher

productivity in the tradable sector. Thus, the relatively higher convergence rates in the tradable sector presented in Table 3.6 suggest that developing economies have more catching-up to do in the tradable sector than the nontradable sector, which would also be consistent with the Harrod-Balassa-Sameulson effect outlined above, since wealthier countries tend to exhibit higher levels of productivity.

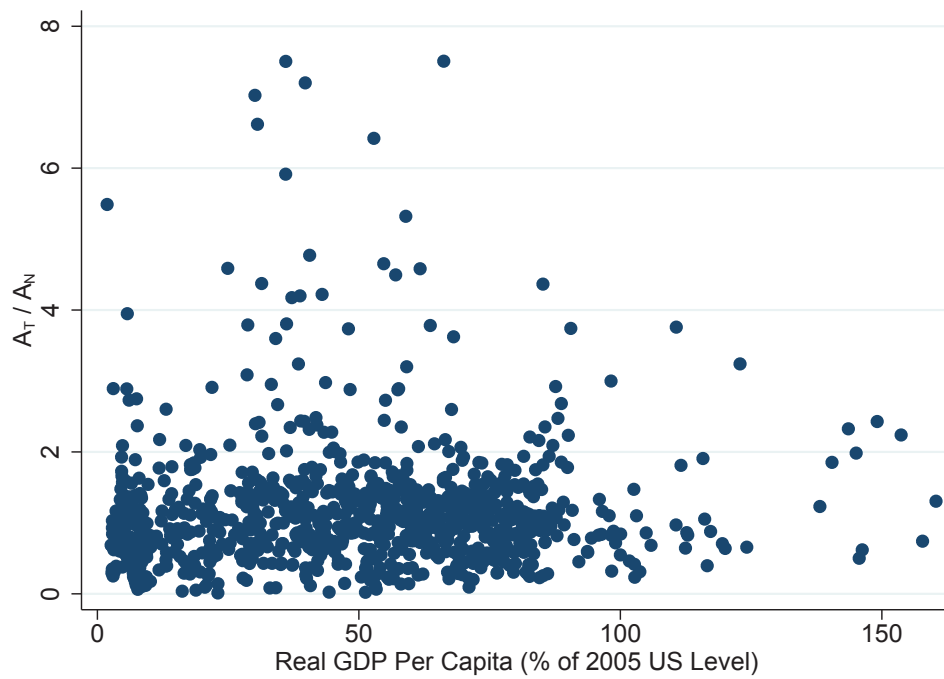


Figure 3.5: Relative Sectoral Productivities and GDP Per Capita

Regressand	Regressors	
A_T/A_N	GDP Per Capita	Intercept
Est. Coef.	.0015*	1.09
Robust Std. Err.	(.0009)	(.055)
95% Conf. Int.	[−.0002, .0032]	[.983, 1.20]
No. Obs.	968	
R^2	.0025	

Table 3.8: Relative Productivities Regression Results (* and *** denote statistical significance at the 10% and 1% levels, respectively).

3.4 VAR Analysis

The biggest difficulty in identifying a relationship between productivity growth and an economy’s tradable sector (even assuming accurate estimation of TFP itself) is overcoming issues of endogeneity stemming from simultaneous two-way relationships. In other words, one can’t perfectly deduce the effect of tradable-sector characteristics on productivity unless one also controls for the possibility of TFP growth affecting the characteristics of the tradable sector. For example, tradable-sector firms enjoying a high degree of productivity may be desirous to forgo additional wage expenses by hiring less labor while maintaining the same level of output. Therefore, regressions that only focus on the effect of hiring additional tradable-sector workers on growth (e.g. Rodrik (2008) and Chapter 1) may not be getting the full picture.

In this section, in order to take such simultaneous effects into account, I make use of a structural panel vector auto-regression (VAR) approach (similar to Ravn et

al (2012), Canova & Ciccarelli (2013), Love & Zicchino (2006), and based on Holtz-Eakin et al (1988)) to identify the relationship between productivity growth and the tradable sector. Specifically, I first focus on the effect of tradable-sector labor shares (as proxied by “employment in industry” as a percentage of total employment from the World Bank’s WDI⁴) on tradable-sector TFP growth (as a percentage deviation from its trend level using an HP-filter, as TFP is generally growing over time and accurate VAR estimates require stationary data). I use a panel VAR approach rather than a country-by-country analysis in order to overcome the weakness of the data in terms of the range of dates covered, which is fairly low for developing countries. In the interest of accuracy, I drop those countries which contribute fewer than five years of data.

Specifically, let y_{it} represent a 3x1 vector time series for country i across time t . I estimate the relationships of these three variables in the following panel VAR model:

$$y_{it} = A_{0i} + A_i(L)y_{it-1} + u_{it} \quad (3.25)$$

for $i = 1, \dots, N$ (countries) and $t = 1, \dots, T$ (years), and where L represents a lag operator. To begin, the vector of three variables includes: 1) TFP, 2) real exchange rates as a representative of relative prices in the economy [following Rodrik (2008),

⁴Several countries’ time series of industrial labor shares have occasional gaps in the WDI data. In these cases, linear interpolation was used to fill out the missing time series observations in between observed values. However, values were not extrapolated before or after the earliest or latest dates for any variables, resulting in an unbalanced panel.

I use the inverse of “national price levels” from the Penn-World Tables 8.0 (PWT)], and 3) “tradable-sector” labor shares L_T (from WDI). I choose to include only one lag in the estimated models because 1) the Akaike Information Criterion (AIC) and Schwartz Bayesian Information Criterion (SBC) are lower for one lag than two, and 2) lags above three significantly reduce the number of total periods available for estimation, particularly for countries at the low end of coverage with only 5-7 years. The estimated time range is 1980-2011, because WDI data for employment shares starts in 1980 and because the TFP data stemming from Compustat prior to 1980 is dominated almost exclusively by a handful of countries (i.e. the United States, Canada, and the United Kingdom).

In order to identify the structural shocks impacting the system of variables, I use a standard Choleski decomposition based on the following assumptions: 1) TFP grows over time based on variables in the previous period, such that firms in the economy make hiring decisions based on their observed levels of TFP within the same year, and shocks to their hiring decisions don’t affect the current level of TFP; 2) TFP is inherently an indicator of productive know-how and does not immediately respond to price shocks within the same year; and 3) prices exhibit a nominal degree of stickiness, and firms make hiring decisions in every year taking prices as given, implying that prices don’t respond to labor-share shocks within the same year. Based on these assumptions, the underlying structural relationships of the VAR can be identified

and expressed using impulse response functions (IRF).⁵

I first focus exclusively on tradable-sector TFP, as the results of the previous section suggest that that is where the effects of technology adoption ought to show up most clearly. Figures 3.6a-3.6c present impulse response functions to structural shocks to tradable-sector employment for regressions using all countries, developing countries, and developed countries, respectively. Dashed-blue lines in all graphs represent 95% confidence bands derived using a “wild” bootstrap methodology. In the case that all countries are collectively included (Figure 3.6a), a positive structural shock to the labor-share in the tradable sector clearly results in a positive effect on TFP growth for approximately the next four years on average. However, the confidence bands show the propensity for TFP growth to also move in the opposite direction in reaction, so the positive impact is not completely statistically significant. However, the result is suggestive of a relationship consistent with the assumptions of Chapters 1 and 2 and Michaud & Rothert (2014) that the tradable sector exhibits some form of learning-by-doing (LBD) effects. However, Figures 3.6b and 3.6c exhibit a smaller average effect of tradable labor on TFP, contrary to what a global technological frontier might suggest.

By comparison, Figure 3.7 presents comparable results using *aggregate* TFP estimates as opposed to strictly tradable-sector TFP. When again considering all countries in the data set, the results are essentially of the same sign and same magnitude.

⁵Response functions are based on shocks with a magnitude of one standard deviation of the sample data.

However, when split into separate “developing” and “developed” groups, the positive effect of a shock to tradable employment is significantly higher in developing countries when compared to developed economies (approximately a 1% growth premium), as would be consistent with the existence of global frontier. Considering the previous results, this suggests that the full benefit to developing economies from exposure to international markets is not only the know-how acquired by the firms directly competing with foreign producers, but also gains in efficiency that are achieved in the nontradable sectors of the economy as well. For example, a manufacturer who learns how to improve the efficiency of her production so as to be more cost competitive internationally is likely to develop skills in workers who may subsequently transfer to nontradable sectors. Overall, a 4% increase in the share of labor working in industry contributes to a substantial 2% boost in the growth rate of aggregate TFP in developing economies, as seen in Figure 3.7b.

Figure 3.8a presents an impulse response function for a VAR wherein the productivity externality source variable has been changed to real exports (from PWT data) to test for the existence of LBE effects. Again, I find that a positive shock to the change in exports results in an accelerated rate of TFP growth, suggesting the existence of LBE. Again, however the confidence bands suggest that this positive relationship must only be considered as an average effect.

Finally, by way of comparison, I also consider the use of a standard, macro-approach, income-accounting, residual estimate of TFP from PWT data in place

of the micro-derived TFP estimates used previously. In this case, I still find some evidence that a shock to tradable-sector employment has a positive effect on TFP growth, although the magnitude of the effect is substantially lower than in the previous analyses. Again, the reliance on an aggregate production function framework and inaccurate measurement of aggregate variables may be leading to significantly different results.

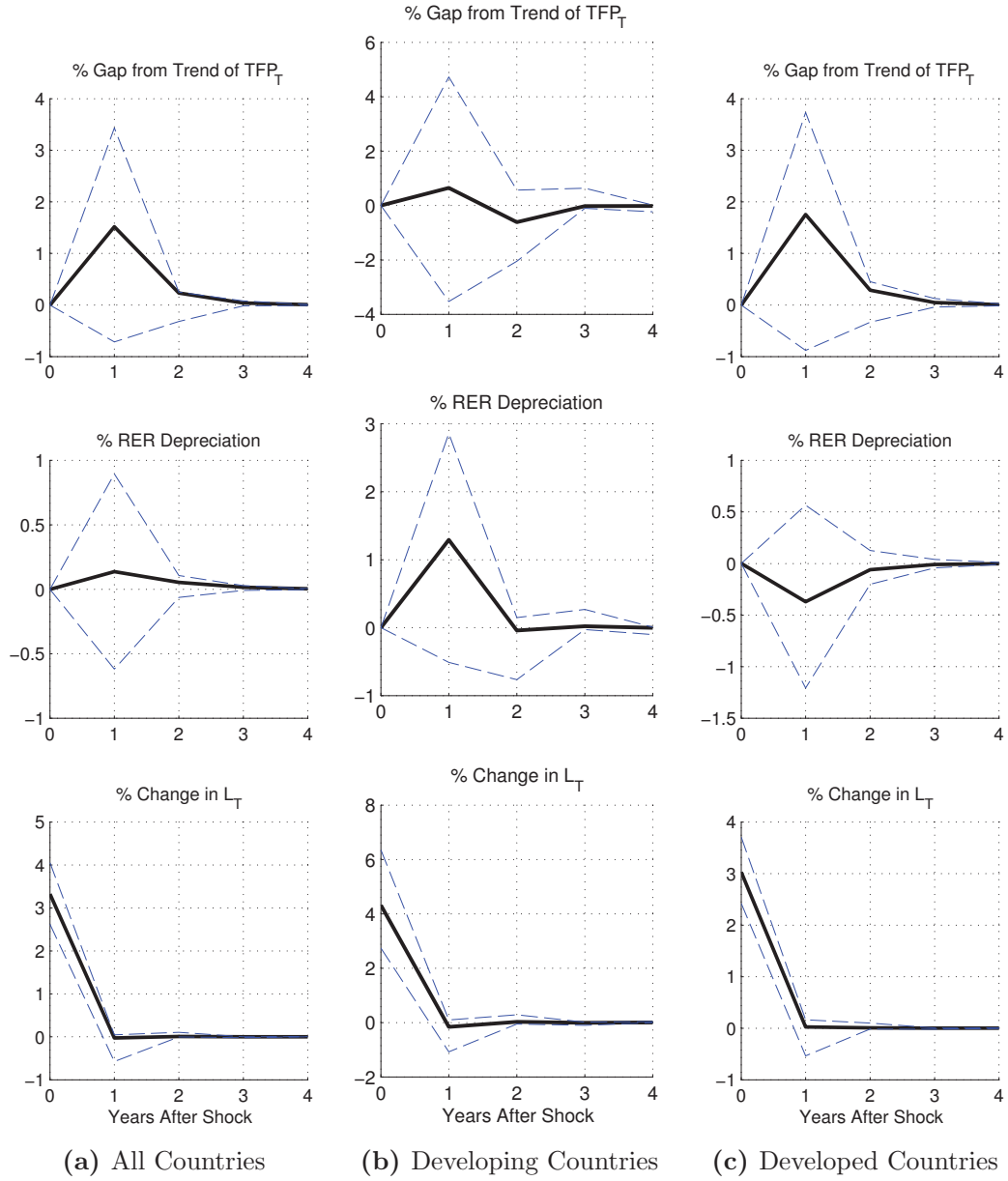


Figure 3.6: Tradable-Sector TFP: IRF to Tradable-Sector Employment Shock (dashed lines are 95% confidence bands)

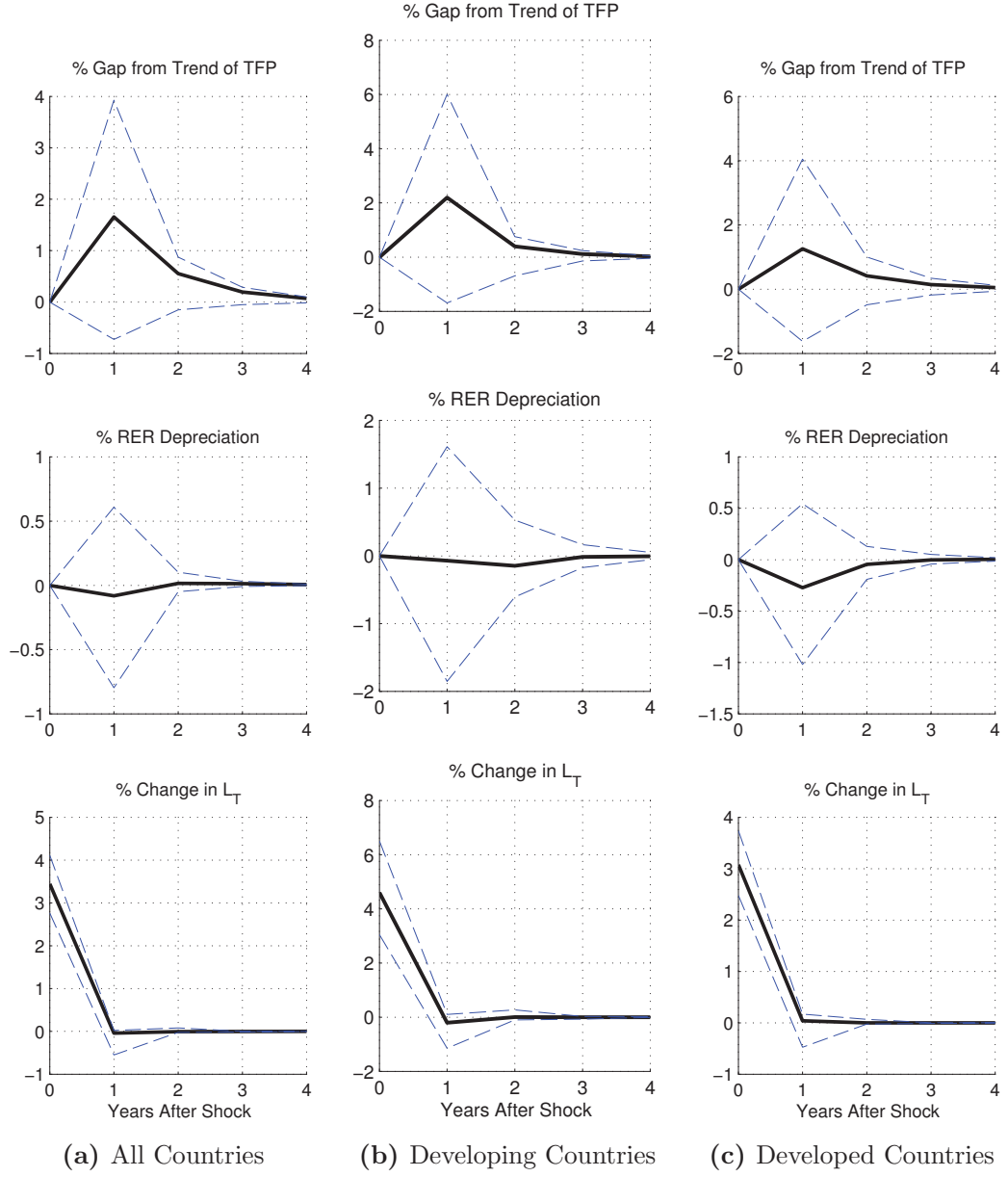
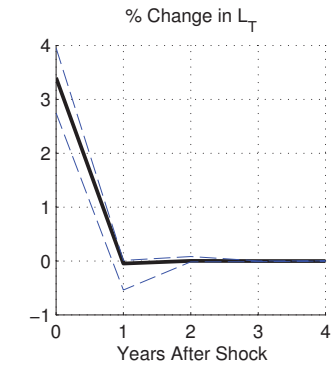
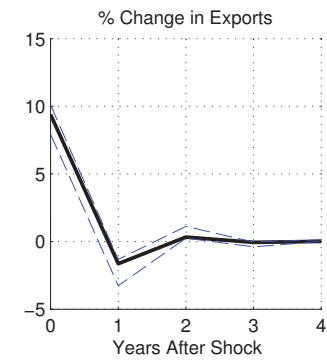
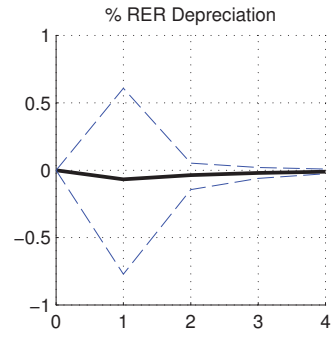
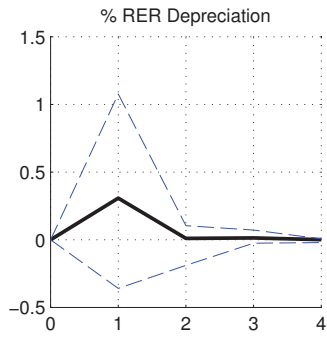
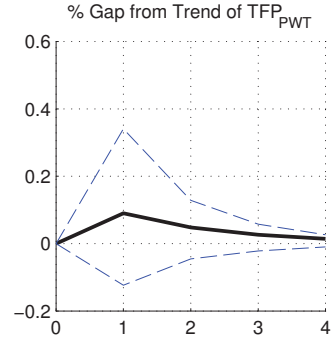
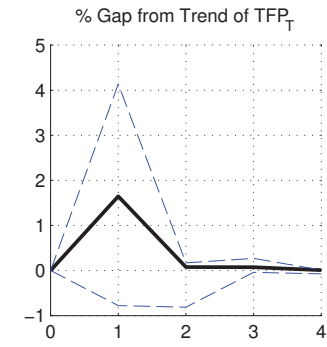


Figure 3.7: Aggregate TFP: IRF to Tradable-Sector Employment Shock (dashed lines are 95% confidence bands)



(a) Exports

(b) Macro-residual TFP (PWT)

Figure 3.8: Alternative VAR IRFs (dashed lines are 95% confidence bands)

3.5 Conclusion

In summary, a firm-level approach to TFP estimation provides results that support the previous identification of a Harrod-Balassa-Samuelson effect and cross-country technological convergence. Furthermore, the ability to disaggregate TFP estimates by sectors suggests significant differences in the ways international exposure affects certain segments of the economy. In particular, nontradable-sector productivity may not converge as quickly as tradable-sector productivity, but is nonetheless a significant source of overall economic growth, perhaps particularly so in developing economies.

Most importantly, this paper provides further evidence that the tradable-sector may be a significant source of accelerated growth, both through learning-by-doing and learning-by-exporting effects. Especially in the event that the full extent of the benefits to an economy from international exposure are not internalized by individual domestic firms, then the government may be able to play an important role in boosting welfare by making use of appropriate, so-called “mercantilist” policy to exploit these productivity effects in the tradable sector. The results suggest further work using disaggregated TFP data is needed to fully understand the nature of these complicated relationships, especially as more data becomes available to better represent both larger sections of developed economies as well as a larger number of developing economies. However, the evidence seems to further justify the basic underlying assumptions motivating the theoretical work in Chapters 1 and 2 and Michaud & Rothert (2014).

Appendix

Intertemporal Budget Constraint

The first-order conditions from solving the intertemporal maximization problem in Section 1.1.4.1 imply that the co-state variable λ associated with total assets is time invariant, meaning we can express the associated transversality condition as

$$\lim_{t \rightarrow \infty} m_t e^{-(r^* - g^*)t} = 0. \quad (\text{A.1})$$

By slightly rearranging the dynamic budget constraint in (1.36), multiplying both sides by $e^{-(r^* - g^*)t}$, and integrating over time, we find

$$\int_0^\tau \left(\dot{m}_t - (r^* - g^*)m_t \right) e^{-(r^* - g^*)t} dt = \int_0^\tau \left(w_t - \frac{1}{q_t} c_t \right) e^{-(r^* - g^*)t} dt \quad (\text{A.2})$$

$$\lim_{\tau \rightarrow \infty} m_\tau e^{-(r^* - g^*)\tau} - m_0 = \lim_{\tau \rightarrow \infty} \int_0^\tau \left(w_t - \frac{1}{q_t} c_t \right) e^{-(r^* - g^*)t} dt \quad (\text{A.3})$$

$$m_0 = - \int_0^\infty \left(w_t - \frac{1}{q_t} c_t \right) e^{-(r^* - g^*)t} dt, \quad (\text{A.4})$$

where the third line applies the transversality condition in (A.1). Then by applying the intratemporal equilibrium conditions for wages from (1.22), the exchange rate from (1.24), and real consumption from (1.32), we obtain the intertemporal budget constraint in (1.39).

Model Solution - Laissez-Faire

Using the first-order optimality condition in (1.37) and the intratemporal pricing conditions, we can implicitly define the fixed level of tradable consumption as a function of the co-state variable λ ,

$$c_{Tt} = \left[\frac{\phi}{\lambda} A_0^{*1-\theta} \bar{c}^{1/\sigma-\theta} \right]^{1/\theta} \quad (\text{A.5})$$

Normalizing the assumed functional form of the equation of motion for technology in (1.29) yields the following expression

$$\dot{a}_t = \left(\gamma_0 + \gamma_1 L_{Tt} \right) \left(1 - f \cdot a_t \right) \quad (\text{A.6})$$

$$= \left(\gamma_0 + \gamma_1 \left(1 - \gamma_2 \frac{c_{Tt}}{a_t} \right) \right) \left(1 - f \cdot a_t \right) \quad (\text{A.7})$$

Therefore, once the value of λ is known, one can then solve the differential equation in (A.7) and use the solution for a_t to ascertain the paths of all remaining variables in the model.

In order to find the correct value of λ that satisfies the intertemporal budget constraint in (1.39), I utilize the “time-elimination method” (see Mulligan and Sala-i-Martin (1991)) by considering the equation

$$m'[a] = \frac{\frac{\partial m}{\partial t}}{\frac{\partial a}{\partial t}} = \frac{(r^* - g^*)m[a] + \bar{w}a - \frac{\bar{c}}{\bar{q}}c_T}{(\gamma_0 + \gamma_1(1 - \gamma_2 \frac{c_T}{a}))(1 - f \cdot a)}, \quad (\text{A.8})$$

which defines a new differential equation in m as a function of a , without respect to time. Assuming a specific value for λ , all that is needed to solve this differential equation is an appropriate set of boundary points for m and a . By construction, a must equal $1/f$ in the long-run steady state, and the steady state value of m can be solved for by setting (1.36) equal to zero, substituting in the steady state value of $1/f$ for a , and then solving for m . The differential equation in (A.8) can then be solved backwards from the steady state point at $a = 1/f$ to the point at which $a = a_0$, and then noting the value of m_0 implied by the solution. Since the initial points of $\{a_0, m_0\}$ are given, one can solve for the correct value of λ by finding the unique value that gives a solution to the function for m in (A.8) that corresponds with the given value of m_0 .

Once the paths of total domestic assets m_t and technology a_t are known, then one can solve for the level of net foreign assets in (1.9) using the value of total capital. The capital intensities in (1.21) combined with the resource constraints in (1.14) and (1.15) pin down the aggregate capital stock as follows

$$\begin{aligned}
K_t &= K_{Tt} + K_{Nt} \\
K_t &= \kappa_{Tt}L_{Tt} + \kappa_{Nt}L_{Nt} \\
K_t &= \kappa_{Tt}(L_{Tt} + L_{Nt}) \\
k_t &= \left(\frac{\alpha}{r^* + \delta}\right)^{1/(1-\alpha)} a_t \equiv \tilde{k}[a_t],
\end{aligned} \tag{A.9}$$

such that the normalized level of net foreign assets can be expressed as

$$nfa_t = m_t - \tilde{k}[a_t]. \quad (\text{A.10})$$

Model Solution - Social Planner

Using the equation of motion for technology defined in (A.7), the equation of motion for the co-state variable related to technology in (1.44) can be expressed as

$$\dot{\mu}_t = \left[r^* - g^* + (\gamma_0 + \gamma_1)f - \gamma_1\gamma_2 \frac{c_{Tt}}{a_t^2} \right] \mu_t - \bar{w}\lambda, \quad (\text{A.11})$$

and the expression for marginal utility in (1.43) can be solved for tradable consumption, yielding

$$c_{Tt} = \left[(A_0^* \bar{c})^{\theta-1} (\gamma_1\gamma_2 (\frac{1}{a_t} - f)\mu_t + \frac{\bar{c}}{\bar{q}}\lambda) \right]^{-1/\theta}. \quad (\text{A.12})$$

Therefore, by substituting (A.12) into (A.11), one can derive an expression for the evolution of μ_t

$$\dot{\mu}_t = \left[r^* - g^* + (\gamma_0 + \gamma_1)f - \gamma_1\gamma_2 \frac{1}{a_t^2} \left[(A_0^* \bar{c})^{\theta-1} (\gamma_1\gamma_2 (\frac{1}{a_t} - f)\mu_t + \frac{\bar{c}}{\bar{q}}\lambda) \right]^{-1/\theta} \right] \mu_t - \bar{w}\lambda, \quad (\text{A.13})$$

which is now a function of only μ_t , a_t , and λ . Likewise, one can substitute the expression for tradable consumption in (A.12) into the equations of motion for assets in (1.41) and technology in (A.7) to express those equations in terms of μ_t .

Therefore, the evolution of the social planner's solution can be characterized by the system of three differential equations outlined below

$$\dot{\mu}_t = \tilde{\mu}[a_t, \mu_t; \lambda] \quad (\text{A.14})$$

$$\dot{a}_t = \tilde{a}[a_t, \mu_t; \lambda] \quad (\text{A.15})$$

$$\dot{m}_t = \tilde{m}[m_t, a_t, \mu_t; \lambda] \quad (\text{A.16})$$

Since the first two equations don't depend on the level of assets m_t , one can use the same time-elimination method outlined in the previous section to define a new differential equation in $\mu'(a)$. Then by choosing a specific value for λ , setting (A.13) equal to zero, and substituting the steady value of $1/f$ in for a , one can solve for the steady state value of μ . Then it's possible to solve the differential equation of $\mu'(a)$ for the path of μ as a function of a . Once the path of μ is so defined, the time-elimination process can be repeated, this time by defining a new differential equation in $m'(a)$ utilizing the solution for $\mu(a)$ from the previous step. Then the process is identical to that of the laissez-faire section: solve for the steady state value of m , use the point defined by this steady state value and $a = 1/f$ to solve for m as a function of a , and identify the implied initial value of assets m_0 . If this value is not equal to the given value of m_0 , the process is reiterated for different values of λ until the resulting path for m_t agrees with the given initial value. Once one knows the proper value of λ that satisfies all of the boundary conditions, then it is straightforward to solve for

the paths of all other variables in the economy.

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Vita



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